IN TWO SECTIONS — SECTION 1

MINING engineering

JANUARY 1954

NODULIZING IRON ORES AT EXTACA

MINING engineering

VOL. 6 NO. 1 JANUARY 1954

IN TWO SECTIONS — SECTION 1

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COVER

The feed and the final product are the theme of the article on nodulizing. Herb McClure designed the cover to symbolize the transition of fine material to blast furnace feed.

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—Personnel Service—

THE following employment items are made available to AIME members on a non-profit basis by the Engineering Societies Personnel Service, Inc., operating in cooperation with the Four Founder Societies. Local offices of the Personnel Service are at 8 W. 40th St., **New York 18;** 100 Farnsworth Ave., **Detroit;** 57 Post St., **San Francisco;** 84 E. Randolph St., **Chicago 1.** Applicants should address all mail to the proper key numbers in care of the New York office and include 6¢ in stamps for forwarding and returning application. The applicant agrees, if placed in a position by means of the Service, to pay the placement fee listed by the Service. AIME members may secure a weekly bulletin of positions available for $3.50 a quarter, $12 a year.

MEN AVAILABLE

Mining Engineer-Geologist, 45, married, one child; 20 years experience, 12 in responsible operation positions, 8 as geologist and exploration engineer. Thoroughly experienced all types of underground mining, excellent record for labor relations and production. Fluent Spanish and French. Available immediately; location immaterial. M-52.

Engineer, 25, single, graduate Missouri Mines '52, B.S. in Mining Engineering. Service requirements completed as officer, Corps of Engineers. Knowledge of some electronics; experience includes engineering and administrative supervision of several large construction projects in Germany. Open pit construction, geological, or technical sales work will be considered. Available immediately; location preference, Canada. M-53-746-Chicago.

Mining and Industrial Engineer. Many years experience in exploration, drilling, testing, examination, development and operation of open pit and underground mines, and development of natural resources, domestic and foreign. Inspection and report on natural resources for industrie[illegible] metallic and nonmetallic. Availa[illegible] M-54.

Mining Manager or Chief Engineer, 39, married, three children. Fifteen years broad administrative experience all phases exploration, development, operation with large company in Bolivia. Reliable organizer and producer. Versatile engineering designer. Effective labor, government, public relations. Available short notice, U. S. or foreign. M-55-5311-E-4-San Francisco.

Mining Geologist, 35, married. Nine years experience exploration and development in metal and nonmetallic operations in West. Desires position primarily in office. Available immediately. Prefers Pacific Coast or Southwest. M-56-5311-E-5-San Francisco.

Mining Geologist or Engineer, 27, married. Three years experience metal mining as geologist. Activities included mine prospecting surface and underground; exploration drilling programs and prospect and mine examinations. Two summers engineering experience mining and highways. B.S. degree includes 50 credits geology and 40 credits engineering. Desires position geologist or engineer in Midwest. M-57.

POSITIONS OPEN

Mill Superintendent with technical education and experience in lead and zinc concentration; cyanide experience helpful. Working knowledge of Spanish. Should have some knowledge of maintenance of milling equipment, and be able to take over the operation of plant and the metallurgy. Salary, $4800 a year plus bonus. Location, Central America. F9415.

Shift Boss for underground mine in hard rock, sublevel and shrinkage stoping. Established producer, 2000 tons per day, modern equipment. Salary, about $5820 a year. Location, eastern U. S. Y9341.

Geophysicist with concentrated experience in the field of petroleum, with considerable experience in theoretical and organizational work. Will collaborate with the head of the Div. of Geophysics in his efforts to improve and reorganize his department in such a way as to carry out its functions efficiently. Should be familiar with field geophysical surveying. Duration, one year. Salary, about $12,000 plus travel expenses and living allowance for applicant and family. Location, Turkey. F9296.

Mining Engineers, certified, with coal mining experience. (a) Engineer for mining engineering dept. doing engineering work in construction, mine layout as well as engineering field work. (b) Maintenance Inspector to make periodic inspections of motors and equipment in the mines. Salary to start, $4800 a year and up. Location, West Virginia. Y9500.

Research Associate, 25 to 30, with mining, metallurgical or geology degree, for ore dressing development project on laboratory scale. Salary, $4200 to $4800 a year. Location, New York, N. Y. Y9085.

Junior Mining Engineer, 25 to 30, recent mining or geologist graduate, with some training or experience in surveying. Duties will include surface and mine surveying, drafting, map work, and general engineering duties connected with underground operations. Salary open. Location, New Jersey. Y8930.

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The Emico 105 has many advantages for users of loading and excavating equipment. It's built heavy and strong — actually the first unit ever produced to work under the strains imposed by heavy-duty loading or excavating attachments.

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The two speed bucket control (another exclusive) permits gentle loading of light trucks or throwing the load back in large heavy trucks when loading from the end.

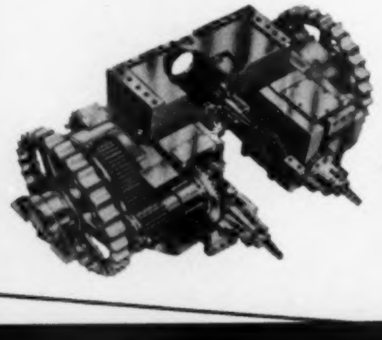
Hundreds of other new features make the Eimco 105 the most popular prime mover on the market. Let us send an Eimco engineer to tell you all the facts.

All of the features of the Eimco 105 are covered by numerous patents issued or patents pending.

THE EIMCO 105 FINAL DRIVE

Eimco's final drive assembly is just one of the new and exclusive features of the new Eimco 105. The Eimco final drive is a rugged heavy-duty assembly made of heavy alloy steel shafts and gears and encased in heavy alloy steel cast housings. The design permits easy access to gearing through side plates. The anti-friction bearings are assembled in cages for perfect fits and longer life.

Notice the absence of troublesome clutches, brakes and gadgets in this sturdy assembly.



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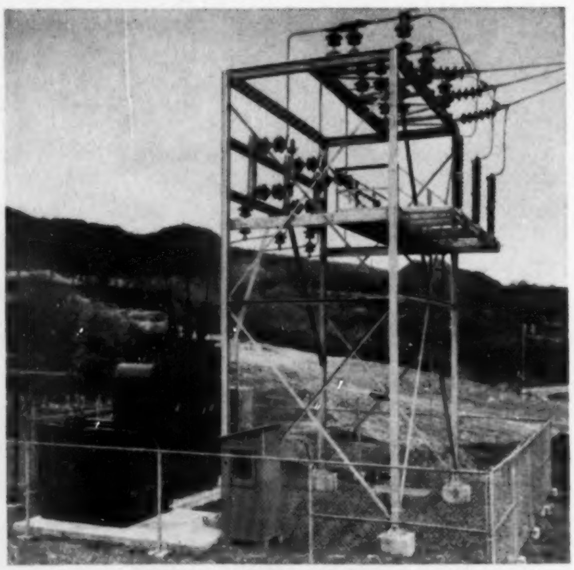
ENGINEERING REPORTS:

Photograph courtesy of Kennecott Copper Corporation

1 STEP UP SHOVEL SPEED, CAPACITY. This shovel performs faster, more smoothly, thanks to its simple, rugged G-E drive system. Usable torque is increased. Response and acceleration are improved. Amplidynes, which control shovel motions precisely, prevent excessive current and torque peaks which might damage electrical and mechanical equipment.

5 ways modern electrification can

4 MAKE POWER SYSTEM MORE FLEXIBLE. This standard G-E cable-skid switch house has polarized couplers to simplify and speed up cable interchanging. Skid house is easy to move.



5 IMPROVE POWER SYSTEM PROTECTION. Magne-blast breakers in G-E master unit substation protect feeders; lightning arresters help guard substation against outage.

toughness... for the roughest screening jobs

CAL-WIC Industrial Screens for the metal mining industry are fabricated of the toughest steels and alloys to give long life and long-run economy. Whether for processing, cleaning, grading, filtering or screening, there is a correct weave, weight and opening. Reduce downtime in your screening operations by installing CAL-WIC Industrial Screens.

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THE COLORADO FUEL AND IRON CORPORATION—Denver and Oakland
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2069

Manufacturers News

New Products • FILL OUT THE POSTCARD FOR MORE INFORMATION • Equipment

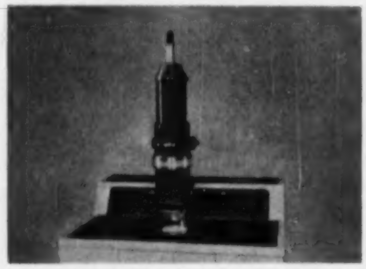
New Side-Dump

The new *Easton Car and Construction Co.'s* model TD-1832H side-dump trailer, built to work with Caterpillar DW20 tractor, has successfully passed on-the-job tests

hauling 32-ton earth loads on strip and fill operations. Big tires, low center of gravity, and outboard mounted hydraulic jacks are designed to insure lateral stability, even while dumping on the run. **Circle No. 1**

Electron Microscope

Suitable for research and analytical work in industrial processing, a new electron microscope available from *North American Philips Co.,* offers magnification from 1,500 to



15,000 diam. Resolving power is better than 100 A under average conditions. The new Philips EM-75 microscope is about half the cost and has approximately half the power of the large EM-100 unit. **Circle No. 2**

Protection

Iron-Rubber protective sheeting made by the *Magic Chemical Co.* is applicable to chutes, hoppers, launders, ducts, housings, shaking tables,

and tanks. Photograph shows a sheet of this Magic-Vulc product on a shaker screen at point of impact where gravel and stone fall from conveyor. **Circle No. 3**

Moisture Meter

To make possible moisture tests in minutes, not hours, *Heyl & Patterson Inc.,* has introduced the portable Olivo moisture meter which gives readings on powdered and granulated material in less than 2 min. **Circle No. 4**

Boomstop for Safety

The Rud-O-Matic Boomstop aims to prevent boom kinking and twisting, stop accidents before they start, by automatically cutting power off the moment the boom is raised too high. One model for cranes to 20 tons and another for 20 to 100-ton capacity units are available. *McCaffrey-Ruddock Tagline Corp.* **Circle No. 5**

Voltage Regulator

Franklin Products Inc. claims its Acutrol regulator will help cut down the battery and generator troubles said to be cause of 40 pct of on-the-job breakdowns of heavy equipment. Regulator measures gas pressure in battery and is claimed to up battery life. **Circle No. 6**

Caulking Compound

C. A. Woolsey Paint & Color Co. has brought out a line of caulking compounds based on Thiokol liquid polymer with use suggested for large steel plate fabricated tanks and vats containing corrosive liquids. **Circle No. 7**

Level Control

Tektor level control capacitance unit has no moving parts and uses a simplified electronic circuit. Control as close as 1/16 in. of liquid, or wet or dry solids, under conditions to 2000 psi and temperatures to 1500°F is provided in this Fielden instrument from *Robertshaw-Fulton Controls Co.* **Circle No. 8**

Vibration Relay

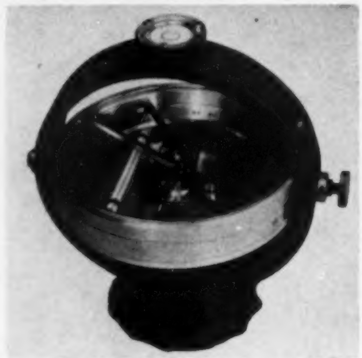
A new relay for protection against excessive vibration due to unbalance in large rotating equipment has been announced by *General Electric Co.'s* special products div. It can be used at speeds from 300 to 18,000 rpm, and is sensitive to frequencies from 5 to 300 cps. **Circle No. 9**

Screens

Mesabi type vibrating screens in 4, 5, and 6-ft wide sizes have been redesigned by *Pioneer Engineering Works* to give heavier service, more efficient operation, and greater durability. Main frame of 4-ft unit now includes an 18-in. car channel, reinforced with 8-in. cross beams, while the 5 and 6-ft models incorporated 18-in. I-beams reinforced with 8-in. beams. **Circle No. 10**

Magnetometer

The Sharpe D1-M magnetometer is now available in the U. S. Lightweight and simplicity of operation



are combined with high sensitivity and accuracy according to the *Radiac Co.,* the distributors. **Circle No. 11**

Power-Crowd Loader

Lessmann Mfg. Co. has announced improvements on all three models of the hydraulic Power-Crowd loader which now exerts a forward thrust of 15,000 lb while the unit is standing still. This permits shovel loading of frozen sand and aggregate and digging in unusually hard or compacted soils. **Circle No. 12**

Coal Hauler

A 40-ton bottom dump coal hauling trailer was announced by *Athey Products Corp.* New PH20 trailer,

engineered to match the Caterpillar DW20 tractor, has already been in service in several Illinois coal mines. **Circle No. 13**

Trucks

Sixteen truck for Orinoco Mining Co.'s Cerro Bolivar, Venezuela, operation have been shipped by *Mack Trucks Inc.* The model LRSW off-highway units will handle 35-tons of iron ore and have 300 hp Cummins diesels, with Twin Disc Converters and Parkersburg Hydrotarders to cope with downgrades. **Circle No. 14**

Safe Ladders

Precision Equipment Co. is building an "automatic action" safety ladder for use in plants, stockrooms, and warehouses. Easily rolled to position, ladders have casters that disengage to make ladder immovable. **Circle No. 15**

Free Literature

(21) SMALL CYCLONE: *The Dorr Co.* has issued a bulletin on its multiple unit TM DorrClone for fine sizing of clays, starches, fillers, and pigments. The unit is said to be capable of separations in the 2 to 20 micron range.

(22) MOTORS: A new line of totally enclosed, fan-cooled motors in ratings from ¾ to 20 hp is described in brochure from *Lima Electric Motor Co.* One feature of motors is the cast aluminum fan to provide high velocity air flow over the integrally cast cooling fins.

(23) HARD SURFACING: A bulletin on the Sprayweld process, which combines metal spraying and torch fusing for simplified, fast application of hard surfacing alloy, has been issued by *Metallizing Engineering Co.* Typical uses are outlined in the booklet.

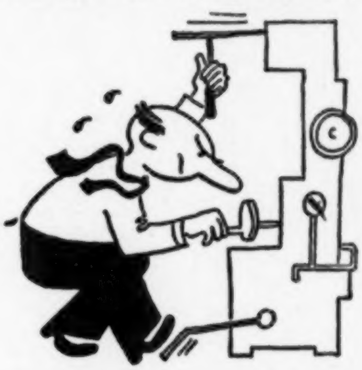
(24) SCRAPERS: Application of scrapers to earthmoving and bulk materials handling is subject of "A Good Business Deal," booklet written in form of an open letter to the earthmoving business from the *Caterpillar Tractor Co.*

(25) REAGENT FEEDERS: Bulletin 541 from the *Clarkson Co.* announces that its model E reagent feeder is now available in unplasticized polyvinyl chloride which has good corrosion resistance. Model E feeder is still manufactured in stainless steel and other special purpose materials.

(26) WEIGHING: Literature from *Weighing Components Inc.* on a platform weighing scale adaptable for batch or continuous process control outlines features for pneumatic transmission of data to indicator, and high accuracy.

(27) AIR COOLED KILN END: *The Allis-Chalmers Mfg. Co.* has released information on an air-cooled kiln end, designed and built to keep the discharge end of kilns cool, round, and rigid. Available as an integral part of new kilns, or as a replacement item, the air-cooled kiln end will pay for itself in fuel, refractory brick, and downtime savings, according to the bulletin.

(28) PRODUCTION CONTROL: "Automatic Production Control", from the *Reeves Pulley Co.*, covers



the complete line of automatic controls available on Reeves variable speed drives.

(29) ABRASION CONTROL: *Goodall Rubber Co.* has a booklet on protection of metal equipment from corrosion and abrasion by means of rubber and synthetic linings and maintenance coating. Products can be applied in the field.

(30) DIRECT LINE TELEPHONES: How executives can raise their own efficiency through direct inter-office communication is told in a booklet from *Automatic Electric Co.*

(31) LOCOMOTIVES: Illustrations, specifications, and application suggestions are given in a comprehensive 40-page catalog from *Jeffrey Mfg. Co.* describing trolley, cable reel, and battery type locomotives in sizes up to 50 tons.

(32) HARDFACING: *Air Reduction Sales Co.* is offering a 12-page reprint of "Selection and Evaluation of Methods of Hardfacing," that appeared in "The Welding Journal."

(33) DIAPHRAGM VALVES: Complete performance and construction details of the Grinnell-Saunders diaphragm valve are presented in a catalog from *Grinnell Co.* Key feature of the valve is simplicity of operation—as simple as pinching a rubber tube.

(34) LIFTS & HOISTS: Condensed catalog from the *Coffing Hoist Co.* contains illustrations, descriptions, and specifications for over 100 types of portable chain, ratchet lever, spur gear, and electric hoists.

(35) TUNGSTEN-MOLYBDENUM: A revised edition of a booklet describing Murex tungsten and molybdenum products is now available from *C. Tennant, Sons & Co.* Outlined are the physical and mechanical properties of these metals in rod, wire, sheet, and bar form.

(36) TRACK CLEANING: *The American Mine Door Co.* has announced its Canton track cleaner in a brochure presenting comparative cost figures for hand and machine track work. Some advantages presented are the reclaiming of track spillage, higher car loading, increased tonnage, saving in man-hour costs, and reduced accidents.

MAIL THIS CARD

for more information on items described in Manufacturers News and for bulletins and catalogs listed in the Free Literature section.

Mining Engineering **29 West 39th St.** **New York 18, N. Y.**

Not good after April 15, 1954 — if mailed in U. S. or Canada

Please send me { More Information ☐ / Free Literature ☐ / Price Data ☐ } on items circled.

1	2	3	4	5	6	7	8	9	10
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41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	Students are requested to write direct to the manufacturer.								

Name________ Title________

Company________

Street________

City and Zone________ State________

(37) VIBRATORS: *The Cleveland Vibrator Co.* has recently published a 16-page illustrated catalog on air vibration equipment, including metallic-impact types and air-cushioned vibration equipment which operates with a minimum of noise.

(38) CARBOLOY MINING TOOLS: The Carboloy Dept. of *General Electric Co.* has a comprehensive catalog, and maintenance instruction manual on carboloy cemented carbide mining tools. The full range of bits, cutters, and drills is fully illustrated, and detailed maintenance information is graphically presented.

(39) PLASTIC PIPE: In an announcement of its newest product *Republic Steel Corp.* tells why it entered the plastic pipe field, describes the two principal types of plastic pipe made, shows how to join plastic pipe, and lists various engineering and corrosion properties.

(40) EFFICIENCY: Twelve photographs in "Plugging Profit Leaks in Mining" show how Caterpillar diesel engines and electric sets are easily made available to any application in all types of mining. Individual job stories and specifications complete this *Caterpillar Tractor Co.* booklet.

(41) MINING & QUARRYING STEELS: In a 20-page booklet from *Bethlehem Steel Co.* four groups of steels for the mining and quarrying industries are discussed: hollow and auger drill steels for blast hole drilling, solid drill steel, broaching and channeller steels, and stone dressing steels. A special chapter is devoted to ultra-alloy steels.

(42) DIAMOND BITS: Coldset Shark Tooth diamond bits made by the *American Coldset Corp.* are covered in a recent folder and price list.

(43) TUNGSTEN CARBIDE PARTS: *Sintercast Corp.* has an illustrated booklet describing sinterforge made-to-order tungsten carbide components for wear and impact applications.

(44) METAL DETECTOR: Form E. 42 from the Engineering Products Dept., *RCA Victor Div.* describes the RCA Universal electronic metal detector which detects any kind of metal or alloy, magnetic or nonmagnetic—including manganese, steel, copper, aluminum, stainless steel, brass.

(45) HANDLING AND PROCESSING: *Jeffrey Mfg. Co.'s* 43-page catalog No. 860 explains Jeffrey's broad facilities to cope with handling and processing problems "of any type and size under almost any condition, usually with standardized units."

(46) SILICA SAND: A flowsheet study on recovery of low iron silica sand by flotation, available from *Denver Equipment Co.*, describes each step of the process and deals with such typical problems as corrosive pulp conditions, slime-free washed sand, etc.

(47) BITS: *Ingersoll-Rand Co.* shows the complete range of Carset Jackbits for use with most popular threaded connections in form 4146. A selection guide aids in choosing the right Carset bit for each connection and application.

(48) MAGNETIC SEPARATION: *Stearns Magnetic Inc.* offers complete research facilities for investigation of magnetic separation problems. Available are details on testing of sample material.

(49) AIR COMPRESSORS: *Worthington Corp.'s* new bulletin No. H-850 covers its line of portable "Blue Brute" air compressors with capacities from 30 to 600 cfm.

(50) GAS CONDITIONER: Diesel engine exhaust gas conditioning is explained in an 18-page booklet from *The Ruth Co.* Writes Joseph P. Ruth: "Regardless of the amount of ventilation, conditioners are an absolute necessity on diesel operated underground equipment. Workmen should never be permitted to breathe untreated diesel exhaust even in an air stream moving at high velocity."

(51) MOTORS: *General Electric Co.'s* Tri-Clad "55" motors built in 1 to 30 hp ratings to latest NEMA dimensions are described in three new 4-color picture-story bulletins, GEA-6012, 6013, 6027.

(52) CLUTCH MANUAL: Eight-page clutch service manual for *Lipe-Rollway* type TC heavy duty truck clutches lists detailed maintenance, overhaul, assembly, and installation instructions. Data chart names dimensions, pressure spring, and pressure plate refacing data for 35 different Lipe clutch models.

(53) CONVEYORS: Published by *Stephens-Adamson*, "The S-A Conveyor" is for users of materials handling equipment. The current 14-page issue is illustrated with photographs and schematic drawings.

(54) INSULATION: *Pittsburg Corning Corp.'s* "Foamglass, The long-life, all-temperature pipe insulation" features on-the-job installation photographs pointing out the advantages of cellular glass insulation for pipe temperatures between —300° and +800°F. Physical properties and condensed recommended specifications are listed.

(55) KILNS: Reprints of a paper written by B. R. Jacobsen, "Rotary Kilns and Their Application for Various Processes," are available from *F. L. Smidth & Co.*, New York.

(56) VENTURI METER: A colorful bulletin on the type MO venturi type flowmeter is issued by the *Simplex Valve & Meter Co.* Available in indicating, recording, and totalizing forms, the meter can be operated as a direct mechanical instrument, or as an electric or pneumatic transmission device.

(57) LABORATORY FACILITIES: The purpose of a brochure from *Ledoux & Co.* is to "describe our new facilities in Teaneck, N. J., and suggest what we can do for you."

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MINING ENGINEERING

29 WEST 39th STREET

NEW YORK 18, N. Y.

Gunnar Gold Mines Ltd. is preparing to spend $14 million for development of its uranium mine 20 miles from Uranium City in northwestern Saskatchewan. Gilbert A. Labine, company president, terms the find the most important in this hemisphere. New diamond drilling has disclosed additional reserves and reports say that the mine will be the biggest in North America. Plans are being pushed to get into production by summer 1955. Gunnar will need a huge delivery of equipment by this summer if the schedule is to be met.

Senator George W. Malone, chairman of the Minerals, Materials, and Fuels Subcommittee, is of the opinion that a change in SEC policy to allow greater latitude in granting permits to sell stock by mining concerns and prospectors in connection with mining operations would result in a maximum return of strategic minerals. The subcommittee is investigating shortage in critical materials, including titanium.

Aluminum Co. of Canada's Kitimat aluminum reduction project is expected to turn out its first ingots by next April. Initial capacity is scheduled for 90,000 tons per year. Ultimate capacity is expected to be 550,000 tons.

Business spent an estimated record sum of $27,827,000,000 during 1953 for new plants, according to the Dept. of Commerce and the SEC. It was anticipated that all industry groups, except mining, would make higher expenditures in the fourth quarter of 1953 than previously reported.

Crisis in the Bolivian mining industry was blamed on falling ore prices by the Banco Minero de Bolivia. It was also disclosed that the Bolivian Government is subsidizing mineral production to maintain output. It was reported that the Government, in addition to subsidizing tin, is lending a hand to copper, lead, and antimony properties.

Consolidated Mining & Smelting Co. curtailed zinc operations because of unfavorable market conditions. A zinc oxide plant and one slag fuming furnace have been shut, according to the company. The production cut will amount to 130 tons of slag zinc per day, or about 25 pct of present Consolidated output.

Steel company officials, whose firms are investing more than $500 million in development of taconite production on the Mesabi Range predict that 12 million tons of taconite per year will be shipped from Minnesota by 1958. R. T. Elstad, president, Oliver Iron Mining Div., U. S. Steel; C. L. Kingsbury, vice president, Reserve Mining Co.; A. D. Chisholm, general manager, Pickands, Mather & Co.; and H. C. Jackson, secretary, Erie Mining Co., speaking at St. Paul, also agreed that annual production of concentrates is expected to reach 23 million tons by 1963.

"Only tractor that will stand up under abrasive action..."

says Silica Mine Owner

E. J. AuBuchon

about Tournatractor

AuBuchon Silica Mining Co., Crystal City, Missouri, produces silica sand for glass and steel manufacturing. They are currently working a 40-ft. strata of St. Peter's sandstone, which is blasted and then truck-hauled to the crushing and screening plant.

Formerly, this company used crawler-tractors to strip sandy clay and rock overburden from the pit. However, the rough rock floor, plus the continuous grinding of tracks in silica sand, ruined the crawlers quickly — the last one, according to the owner, was "beyond repair" inside of 11 months. To keep this from happening again, AuBuchon brought in a rubber-tired Tournatractor.

Now, after several seasons of work with rubber-tired tractors, 4 points are apparent:

1 — Tournatractor's big tires roll easily over the rocks which frequently broke track pads.

2 — Tournatractor's sealed anti-frictions keep moving parts out of the abrasive sand which ground away tracks.

3 — Tournatractor's 186 hp, coupled with 19 mph forward and 8 mph reverse speeds, enable it to do most jobs much faster than a crawler.

4 — With normal care and maintenance, Tournatractor should last for years instead of just 11 months.

Commenting further on the superiority of tires over tracks, Company Vice-President E. J. AuBuchon says, "Our Tournatractor is doing a fine job. We have found it is the only tractor that will stand up under the rocky hard floor of our operation. Crawler-tractors just can't take the abrasive action of sandstone."

All-Purpose Tool

There have been production advantages, too. Tournatractor clears trees and dozes overburden and rock up and down wet 8 to 10% grades with little trouble. Its $2\frac{1}{2}$-yd. blade

WHY CRAWL WHEN YOU CAN RUN?

BECAUSE of their outstanding design and efficient performance in the field, Nordberg mine hoists have been chosen by another large copper corporation to meet the exacting specifications for its Arizona copper operation. The reasons behind the selection of three Nordberg 15′ dia. double drum hoists are sound . . . since 1895 Nordberg has held the reputation for leadership in the large hoist field—these hoists are used by major mining companies throughout the world. What's more, Nordberg has been the source of the most progressive hoist engineering advances in the mining industry.

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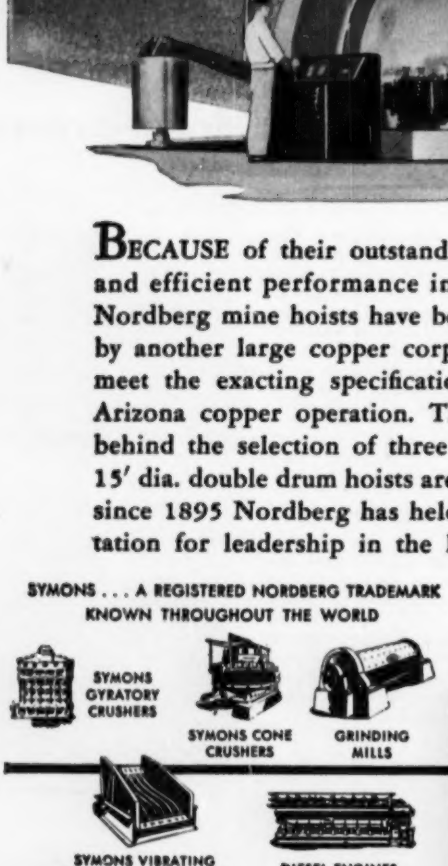
SYMONS . . . A REGISTERED NORDBERG TRADEMARK KNOWN THROUGHOUT THE WORLD



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Erie Mining Co. to Inaugurate Major Taconite Program

Erie Mining Co. has completed plans for financing initial development of its program for construction of facilities in Minnesota for ultimately producing taconite pellets at a rate of 7.5 million tons per year, according to Elton Hoyt, II, Erie president.

Immediate plans call for construction near Aurora, Minn. of the largest initial ore concentrating plant ever to be built. Housing facilities for employees and their families, a 73-mile railroad from the plant to Two Islands, on the north shore of Lake Superior, and a harbor will be built. A large electric power station will also be constructed at Two Islands.

Erie Mining, according to the company, has under its control on the Mesabi Range enough property for the production of raw material to meet maximum requirements of the plant for more than 50 years. Erie has employed the engineering dept. of Anaconda Copper Mining Co. to do the engineering, prepare plans and specifications, and be responsible for construction of the new concentrating plant.

The plant will be 5 miles north and east of Aurora and about 2 miles from the initial mining pit. Ore will be hauled by mine railroad to the plant and unloaded directly into primary crushers.

Equipment and men are already at the site of Erie Mining Co.'s new taconite plant, clearing the ground in preparation for actual construction. The plant will go up near Aurora, Minn.

The single track standard gage railroad will haul outbound finished product from the plant to a port at Two Islands. The harbor, to be known as Taconite Harbor, will be about 4400 ft long and 1300 ft wide. It will have facilities for unloading coal for the electric power plant.

Work has already begun and may lead eventually to a total annual taconite pellet production of up to 10.5 million tons and an investment of more than $300 million. Erie has arranged to sell $207 million of first mortgage 4¼ pct bonds, due in 1983, to a group of nine insurance companies and Bethlehem Steel Corp. Kuhn, Loeb & Co., arranged sale of the bonds. Substantial equity capital has also been subscribed by Erie's four stockholders—Bethlehem Steel Corp. (45 pct), Youngstown Sheet & Tube Co. (35 pct), and Interlake Iron Corp. and the Steel Co. of Canada Ltd. (10 pct each).

Defense Production Administration last year awarded Erie Mining a certificate of necessity for the project on the basis of up to 10.5 million tons annual production. The cost of the entire project was estimated to be about $298 million at that time.

ABOVE: A wall of taconite at an Erie Mining Co. mine near Aurora is one of the areas which has been a source of material during pilot plant stages and will now supply a full scale commercial operation. RIGHT: The preliminary plant was Erie's proving ground for developing processes for a large scale operation.

U. S. Resources Surveyed by Mid-Century Group

The Mid-Century Conference on Resources for the Future was a working conference, with more than 1500 delegates taking part in three days of intense, concentrated discussion on one of the most vital factors in the future of the U. S.

Leaders from every branch of industry concerned with natural resources—government people, university professors, and journalists—came to Washington's Shoreham Hotel. The Conference was initiated by Resources for the Future Inc., a nonprofit group financed by the Ford Foundation. Object of the Conference was to "survey the natural resources of the nation, explore the demands that may be placed upon them during the next 25 years, and investigate methods of use and conservation."

In a few months the thousands of words and multitude of ideas that emerged from the conference rooms will appear in proceedings volumes. At no time during the Conference was it the idea to set up a plan of action. What was desired, what was aimed at, was the accumulation of ideas and data that may show the way for a continued prosperity and resource rich nation. Votes were not taken, resolutions were not approved. In the main, the work remained a process of blocking out areas of agreement and disagreement in an attempt to provide ground-work for future policy making by private and public agencies.

The Conference was organized in eight sections meeting concurrently. Each section dealt with an area of the total resource picture. The sections were: Competing Demands for Use of Land; Utilization and Development of Land Resources; Water Resource Problems; Domestic Problems of Nonfuel Minerals; Energy Resource Problems; U. S. Concern with World Resources; Problems in Resources Research; and Patterns of Cooperation.

Lewis W. Douglas, Conference chairman, introduced President Dwight D. Eisenhower, who spoke briefly in praise of the purpose of the conference, at the first luncheon, held December 2. The President stated his belief in the necessity of the Conference and his deep interest in the work it was doing.

Mr. Douglas, following President Eisenhower's speech, welcomed delegates to the conference, and summed up the work it was to do.

"I would not be stating the proposition with complete accuracy if I were not to say that our national concern also is with the resources for that portion of the world community of which we are a part . . . All societies, from the most primitive to the most complicated, are largely shaped by the resources which their members in one form or another employ directly or indirectly to satisfy the desires and tastes of mankind."

President Dwight D. Eisenhower welcomed conferees, expressing a deep interest in their work and acknowledging its long range importance to the nation. Lewis W. Douglas introduced the President.

He concluded by saying, "This conference, in a sense then, is a measure of our ability to try and define the issues, to suggest re-examination of facts and to propose a review of their meaning within this broad and important sphere of natural resources and to do this with respect for each other . . . It was Acton who said, 'We cannot make men agree but we can make men disagree reasonably.' "

One of the most interesting sessions of direct concern to mining men was Domestic Problems of Nonfuel Minerals, with Evan Just, vice president of Cyprus Mines Corp., presiding. A topic which resulted in much discussion was that of the claim-patent system. While several were for changes in the law as it concerned the prospector, the general opinion appeared to be that proper administration would do much to rectify real or imagined ills.

AIME President Andrew Fletcher, speaking on a panel discussion, warned his listeners that the U. S. was in grave danger of seriously weakening its mining industry.

Delegates tossed in several varying ideas concerning the matter of local double recording. It was pointed out that duplication of claim records entailed expense, time, trouble to the prospector and to the Government. It was felt that as long as claims were registered in local offices, there should be no need for the prospector to submit duplicate papers to another office. However, it was pointed out that the Federal Government did have a valid point in desiring to know the status of public lands. At this time, only active claims are recorded, while others often remain a mystery until stumbled upon. The general opinion appeared to adhere to that of the traditional stand taken by the mining industry.

Other topics taken up by this section included improved exploration of minerals, a proposed bill to provide for the location of mining claims by geological and geophysical prospecting methods, recommendations of the Hoover Commission task force on natural resources, regarding the claim-patent system of mineral locations, and recommendations of the President's Materials Policy Commission regarding revision of the mineral laws.

James Boyd, in one of the earlier sessions of the Conference noted that the problems of resources were complex and that outward manifestations of the situation often were not as they appeared. He said, "Let us take the mining industry as an example of the most acute problem—and it is the one with which I am most familiar. Many laymen have assumed, because sudden increases in demand have not been immediately met by the mining industry, that there is evidence for the exhaustion of total reserves. Experience has shown, however, that shortages may be ephemeral factors brought about by lack of sufficient flexibility of supply, and many of the current problems in the mining industry at least are brought about by an over-correction of the temporary shortage condition. These are symptomatic of one of the greatest difficulties to be faced in resource supply—that of the impossibility of bringing new mines into production in a short time or quickly closing down mines when supply is in balance."

Evan Just served as chairman of the Domestic Problems of Nonfuel Minerals section. The group proved to be one of the most dynamic of the sections.

Andrew Fletcher, AIME President, speaking at a panel discussion, noted that with the increase in the population, there is little doubt that the U. S. will over a period, use more foreign production, but it is difficult to determine "how much" it should depend on foreign resources "in view of the vagaries of the foreign market."

Mr. Fletcher told the panel he did not share the view that the U. S. was a have-not nation. He said, "There is no quicker way that I can think of to drop into the have-not class than to let the mines flood, have no young men coming into industry, have no incentive or organization to find new ore reserves, no desire to develop and improve mining machinery, and to lose the technical know-how."

He pointed out that a failure to develop native natural resources could result in serious damage to the nation. "In my opinion, the best and cheapest stockpile is a prosperous and going mining industry." He again advocated the sliding scale tax, which he said, would give protection only where needed.

Brookings Institute prepared a paper to serve as a background for all sections. The paper suggested four questions that it deemed pertinent to the work of the various groups.

"What will our country be like in the years to come; what population and national output can we expect; and how will changes in the nation's economy be reflected in the type and volume of resource use?

"Can current trends of mounting resource demand and difficulties of supply be expected to continue to a point where resource limitations will hamper the national growth we anticipate?

W. Mc. Peirce, New Jersey Zinc Co.; H. I. Young, American Zinc, Lead, and Smelting Co.; and J. W. Vanderwilt, Colorado School of Mines, contributed to the Domestic Problems of Nonfuel Minerals section.

"Do we know enough about our needs and resources, and those of other nations, to make is possible to anticipate critical shortages? Will science and engineering meet the challenge by developing new materials, new sources of materials, new methods of obtaining them and better ways of using them?

"To what extent will the second half of the century see the material aspirations of less fortunate nations fulfilled; and how might an improvement in the economic conditions of the rest of the globe affect the resource and economic position of the United States?"

Precise results of the Conference will not be known until the proceedings are published. It was felt by many who attended, that at least the compilation will serve to gather together many similar and dissimilar ideas into one area, where they can be seen, studied, and finally evaluated.—M. A. M.

Howe Sound Signs U. S. Copper Pact

Howe Sound Co. of New York has signed an agreement with General Services Administration for delivery of 18.7 million lb of refined copper, according to Edmund F. Mansure, GSA head.

The pact states that the company will provide ore from its "high cost" Holden mine in Chelan County, Wash., and will arrange with a qualified smelter to process the ore. Payment will be 31.50¢ per lb, F.O.B. common carrier's conveyance at any points within Washington, Oregon, California, or Nevada at government option.

The agreement calls for production of 9,020,000 lb on or before Dec. 31, 1954, and 9,680,000 lb during calendar year 1955. An agreement was signed between Howe Sound and the Government in June 1952 for production at Holden of up to 8,834,000 lb of electrolytically refined copper, which because of high cost factors was to be supported at a price of 28.09¢ per lb—4.70¢ over the ceiling of 24.20¢. The price was eventually raised to 32.54¢ per lb. When copper was decontrolled in February 1953, the agreement automatically terminated. At that time, more than 5.5 million lb had been produced.

Until this latest agreement the company has operated the mine without Government contract.

Sherritt Gordon Plant To Operate by April

Sherritt Gordon Mines Ltd. expects to have its nickel refining plant at Fort Saskatchewan, Alberta, in operation by the beginning of April, according to a company official.

Treatment of concentrates will begin about then, with the first production of nickel metal a month later. Delays in delivery of certain essential equipment was blamed for the tardy start of operations.

One unit of the concentrator went into operation at Lynn Lake, Manitoba, in November. Concentrates will be stockpiled at Fort Saskatchewan until the refinery is ready.

Miami Copper Closes Castle Dome Mine

The Castle Dome mine of Miami Copper Co. is near exhaustion, according to the company, and the mine and mill equipment will be moved to the Copper Cities location.

The Copper Cities mine is expected to replace approximately the Castle Dome production once the new mine is in operation. Foundations at Copper Cities have been completed as has preliminary stripping of the orebody. However, the company expects production from its Miami mine only during 1954.

THE tremendous surge mining has made in Canada is illustrated by its position in the total net value of commodities produced by that country in 1951 according to a recently released survey. Government statistics show that a record for value of commodity production was set that year. Total production value was $12,934,430,000, an advance over the previous high of $10,558,557,000 in 1950. The mining industry, in fourth position in 1951, contributed $770,143,000 to the total. In 1950, the mining industry share of total commodity value was $657,329,000. Net value from the forestry industry, next in line during 1951, was $484,264,000, well below mining. As an aside, it should be noted that on the basis of over-all contribution to Canadian commodity value production, Ontario remained well ahead of the rest of the country with a net production of $5,320,040,000.

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ONE of the most ambitious publishing projects of recent times has been that of the Twentieth Century Fund. This group has been responsible for the printing of a great mass of information—with yet more to come. One of their latest products is *World Population and Production*, by W. S. and E. S. Woytinsky. While containing much that can serve as background material for the engineer, a chapter devoted to coal may prove of special interest to many. In what must be termed a limited amount of space, the world coal situation is presented in survey treatment with emphasis on economic aspects, production, history, and reserves.

According to the authors, first estimates of world coal reserves totaled 7.4 trillion tons, with about 10 pct actual reserves, and the rest possible or probable. In 1948 the estimate was revised downward to 6.3 trillion tons, with some 690 billion tons, and an unknown quantity in the U. S., considered to be actual reserves. Estimate of U. S. reserves is 2.9 trillion tons instead of the 3.8 trillion accepted in 1913; Canada, 89 billion tons instead of 1.2 trillion tons; and for the USSR, 1.2 trillion instead of 234 billion. Revised estimates were made by the World Power Conference. The 1913 estimates had shown "practically no actual coal reserves in Russia, which, in the face of growing coal production, defied the realities."

The authors maintain that coal is likely to retain its position as a main source of energy for a long time to come. They point to industrialization of underdeveloped countries, new chemical industries, and experiments in new ways to transport coal, as evidence in support of their contention. The husband and wife author team feel, however, that there will be a realignment of production from individual countries. The U. S., in the future, may account for about 40 pct of the total, "or perhaps even more," compared with 25 pct in the 1930's. The United Kingdom may pass its 1938 production of 231 million metric tons. Germany, the state, will have a smaller share of the world total, while the USSR and Poland will produce more than before the war.

Progress in gasification of coal is briefly summarized. A thumbnail account of Russian endeavors along this line states that the USSR target for the Donets station was 14 million cu ft of gas per hr, equivalent to 0.5 million tons of coal per year. By 1950 the Russians hoped to produce 920 million cu meters of fuel gas. The Russians claim that underground gasification of coal in the Tula coal bed has resulted in recoveries of 80 to 90 pct of the coal, in place of a previous 60 pct.

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ASK five people what the foreman on a specific job does and the five replies are likely to be quite different from each other. The Army recently sent a team of psychologists into the field to determine just what foremen do on the production line. After spending considerable time with a great number of supervisors, they found that foremen, at least, had a solid idea of what their job entailed.

Foremen stress "production and give more attention to machine operations, equipment, stock and quality than to any other phase of their work. The researchers recognized that production is the first order of business on the foreman's agenda." In conclusion they said, according to *The Foreman's Letter*, published by the National Foremen's Institute Inc.: "The production foreman's duty is to expedite the work of his department to the end that the quantity of output meets scheduled expectancy, the quality of the products is consistent with expectations, and the costs of operations are minimal while still assuring attainment of the foregoing goals. Other responsibilities, including the morale of the work group, are means to that end."

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TODAY'S young engineer isn't particularly interested in leaving the confines of civilization for the rugged adventure of engineering projects in far off, uncivilized parts of the world. That's what a report issued by the Professional Engineers Conference Board for Industry says. The report admits there are still some of the more hardy species left, but the average young engineer today is looking for security. The report, *How to Attract and Hold Engineering Talent*, maintains that the young men entering the profession have memories of the depression years well inscribed on their minds. Added to that is the general insecurity of a world in turmoil.

The Survey was made of a group of 1400 engineers and 200 industrial employers. It shows that the engineer is little different from his nonprofessional brother in industry when it "comes to his desire for an adequate pay check and a reasonable expectation that the numbers on that check will be

revised upwardly at pleasantly frequent intervals." The report states that 45 pct of engineers in industry are not satisfied with their salaries; that 34 pct of them do not feel advancement prospects are good; more than half did not know if employers were satisfied with their work; and 38 pct felt that companies were not making full use of their talent and training.

On the other hand, some 62 pct of the employers questioned felt that engineer employees were not well trained by colleges. Incidentally, 28 pct of the engineers agreed to that themselves. The report suggests that there is a feeling that greater emphasis on the humanities, English, and social studies would go far in turning out *educated* engineers and not merely, engineers. A new approach to campus recruiting was also suggested. The report feels that the facts of life and industry should be brought home to the student prospect. Frequently, the student is oversold on a job and becomes bored and disinterested when it fails to meet his expectations. The report also offers the idea that personnel policy concerning the engineer should differ from that for the nonprofessional employee.

It is also felt that management should encourage young engineers in the prestige activities of writing and lecturing on technical subjects. It also urges participation in society and community affairs. Professional societies can do a great deal toward stimulating professional attitudes among all engineers, according to the report. The report is $2.00 per copy for nonmembers of the Professional Engineering Conference for Industry, and $1.00 for members.

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A SEVEN member team is investigating the organizational setup of the U. S. Bureau of Mines. Headed by Curtis L. Wilson, dean of the Missouri School of Mines, Rolla, Mo., the group will also look into operational procedures of the Bureau. The survey team will study operations in Washington and in the field. A final report containing recommendations is expected by Jan. 30, 1954. The Bureau of Mines survey is part of a department-wide study of work of various bureaus and offices inaugurated by Secretary of the Interior Douglas McKay to increase operating efficiency within the department.

The survey group will attempt to determine what is being done; if work is accomplished in an efficient manner; and if there are other means of accomplishing the work more efficiently. Other members of the team, in addition to Mr. Wilson are: John C. Kinnear, Sr., assistant to the director, Office of Defense Mobilization, and prior to retirement in 1951 vice president of Kennecott Copper Corp.; Dennis Lee McElroy, vice president, Pittsburgh Consolidation Coal Co.; J. S. Butler, president, Butler-Johnson Corp.; Spencer S. Shannon, director, materials office of the former National Security Resources Board. Henry Caulfield of the department's technical review staff will serve as staff assistant to the team. Another department official will also be assigned.

TITANIUM is the sixth most abundant element in the Earth's crust. Its importance has multiplied tremendously with development of jet aircraft and certain military weapons. Army and Air Force spokesmen feel strongly that production is way behind demand. Unless something is done to increase the supply of titanium available for jet aircraft, at least one Air Force general feels U. S. air power won't be strong enough to win a war. This is what Senator George Malone's Subcommittee on Strategic Minerals, Materials, and Fuels heard during recent titanium hearings.

Brig. General Kern D. Metzger, chief of the Aircraft Resources Div., says that the insufficient number of plants for processing ilmenite and other ores offers a "dismal picture." Even when viewed optimistically, the general said, present production outlook shows that titanium for only 2000 fighter planes will be available over the next five years. "That won't win any war," he said.

Another witness, E. A. Gee, manager of the plants technical section, pigments dept., E. I. du Pont de Nemours & Co., told the Subcommittee that all the raw material needed for titanium production is available in Canada or in the U. S. His main line of testimony was that at this time development of new processes is more important than raw material availability.

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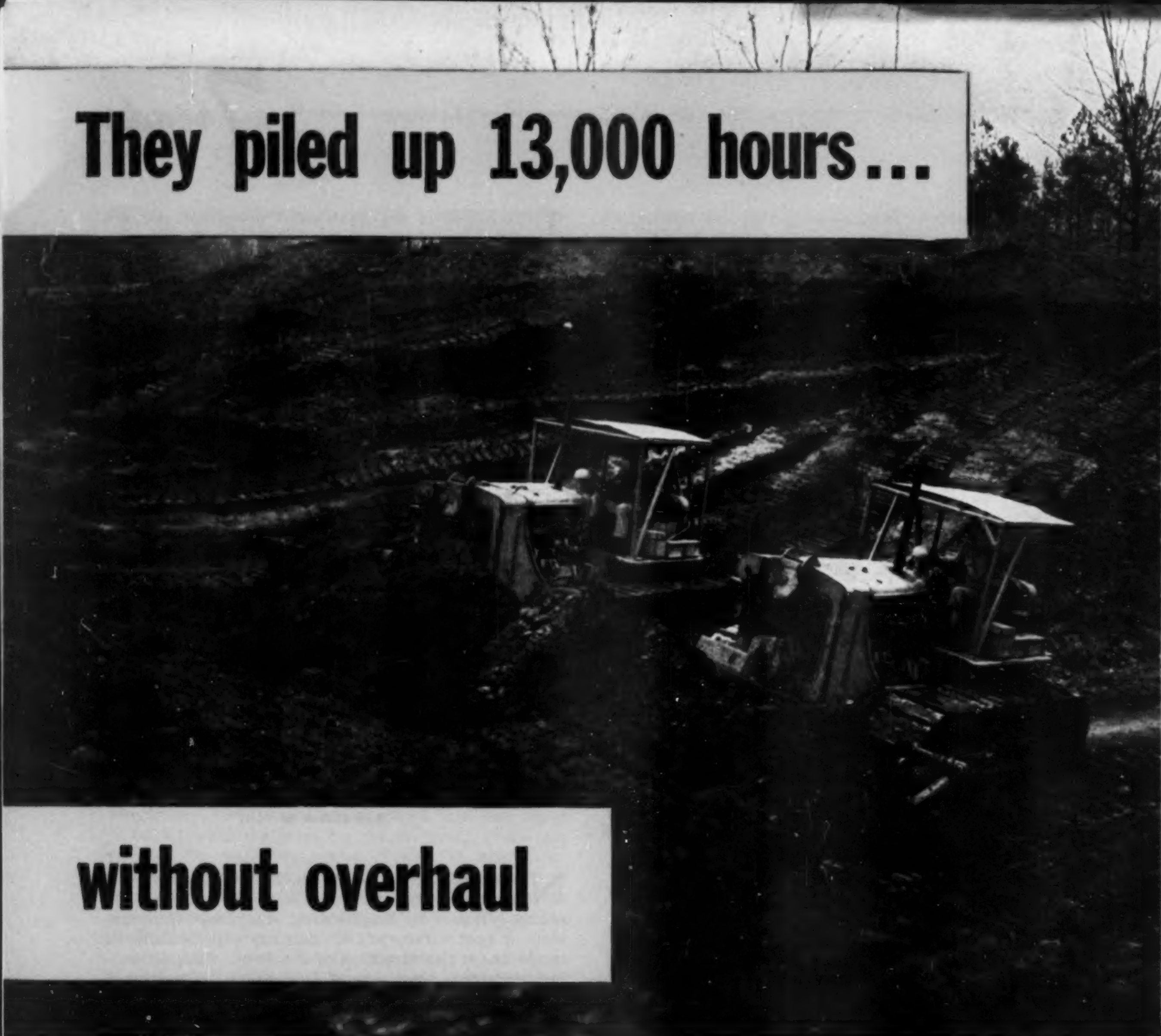
NO appreciable slackening in the demand for technical graduates can be seen in figures recently released by Engineering Manpower Commission. A spot survey of 143 company representatives, made under the direction of Philip H. Yost, personnel assistant, Connecticut General Life Insurance Co., showed that 30 pct wanted more graduates in 1954 than in 1953; 24 pct wanted fewer; and 52 pct wanted the same number.

One year ago, figures for the same survey were: 33 pct wanted more; 10 pct wanted less; and 56 pct wanted the same number. Figures apply to technical graduates including engineers.

Questions on salary range to start revealed that 77 of these companies were offering the same salary in 1954 as they offered in 1953, 62 companies were offering higher salaries. In answer to specific salary range inquiries, the survey group tallied this way: 8 pct stated a figure between $301 and $325; 36 pct quoted a range between $326 and $350; and 44 pct were between $351 and $375. Results for a year ago were: 42 pct, $301 to $325; 43 pct, $326 to $350; and 6 pct $351 to $375. No one intends offering a lower salary this year.

Three companies reported that they were able to hire between 0 and 25 pct of the men they sought in 1953. Another 24 company representatives stated they hired between 26 and 50 pct of the men they wanted, 24 more got 61 to 75 pct, and 64 hired between 76 and 100 pct of the men they sought. The survey was taken at the annual meeting of the Midwest College Placement Assn., in Milwaukee.



Between them, these two Caterpillar D7 Tractors with No. 7A Bulldozers have worked more than 13,000 hours before being overhauled. One has 6000 hours with no overhaul yet; the other went more than 7000 before visiting the shop. Owned by Bob Hawkins Construction Co. of Fort Deposit, Ala., they are shown 'dozing out settling basins at an iron ore stripping operation for Greenville Mining Co.

Ore averages 46-55%. Dirt must be removed regularly from the basins after settling. That means summer and winter operation for these sturdy yellow machines. Quick-starting, they need no pampering even on coldest winter days. They have stamina to work in frozen materials, and balance and traction to keep going when it's sticky underfoot. They're built to work the year around—or as far into the winter as *you* want them to work, and then get you off to an early start again in the spring.

These are all reasons why many mining operators winterize with Cat* machines. These big yellow bruisers pay off the year around with dependable high production. They stand up to equipment-busting mine work, thanks to extra-sturdy construction and special high-strength steels.

Your Caterpillar Dealer offers a wide range of tractors and matching bulldozers. He will arrange a practical, on-the-job demonstration of the dependable Cat-built team that suits your job to a "T." Call him now—and count on him whenever you need fast, skilled service and genuine Caterpillar parts.

Caterpillar Tractor Co., Peoria, Illinois.

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Drift of Things

NEXT month at the New York AIME meeting Reno Sales becomes the first Jackling Lecturer in a new series inaugurated by the Mining Branch. Even to the younger mining people the name Jackling will bring the word *copper* to mind almost automatically. Why this name might just as well bring the word *iron* to mind is the theme of the article on page 30.

As far as we know this article in MINING ENGINEERING is the first recent reference to Jackling's venture in taconite beneficiation. In all the reams of publicity written about taconite there has been little mention of the plant that went into operation on the Mesabi 30 years ago, let alone of the fact that this pioneer plant produced over 150,000 tons of sinter prior to being shut down by the drop in iron ore prices in 1924.

Announcement in the past few days of Erie Mining Co.'s $207 million mortgage financing of its 7.5 million ton per year taconite plant underlines the importance of this story.

This sketch of a little-known facet of Jackling's career serves to introduce a group of articles on three phases of Iron Range developments: mining, beneficiation, and agglomeration. A comparison of Jackling's pioneer plant with those going into operation today reveals remarkably little change in process, although equipment has been improved and modernized. Greatest change has been in the agglomeration step, where several alternatives to sintering are being tested. On this problem of agglomeration there has been a tremendous research effort involving almost every major steel company. In this connection MINING ENGINEERING is pleased to present another first, the detailed account of Oliver Iron's use of the rotary kiln for agglomeration. See page 32. —R.A.B.

REFERRING again to the "wizard of low cost production," the Mining, Geology, and Geophysics Div. established in 1953 a special lecture, the standards for which demanded the name of a mining man who exemplified the strong, long-established tradition of the industry, "foresight and resourcefulness".

D. C. Jackling became the obvious choice, because here is a person who occupies the same position in the population statistics as all others, but his existence has altered to a great degree all other statistics. He is the "father of the porphyry coppers," and was responsible for the early beginning of mining and processing ores on a mass production scale that is now the major source of the copper mined in the U. S. and other parts of the world. This is really a fabulous comer who makes all us mortals stand in awe. It is not that he had a patent on the idea or that it would never have come to pass without him, but the timing is the essential feature.

Having delayed somewhat in arriving at another important facet of the newly created Jackling Lecture, the man chosen as the first to receive this honor—Reno H. Sales, chief geologist of Anaconda Copper Mining Co.—is in his own right another of the giants of U. S. mining, past and present.

His career is one revolving around the low grade copper enterprises. Through him the knowledge and understanding of the massive orebodies responsible for many social advances have been vastly increased. The present day geological notation used in mapping is result of his efforts.

During the 1954 Annual Meeting these two names will be permanently inscribed on the honor rolls of the mining profession when Reno H. Sales will deliver the first D. C. Jackling Lecture. Drawing from the vernacular of the advertising field, "this will be a fabulous event."

RECEIVING the following type of correspondence at Institute headquarters is always a very great pleasure to staff members. Dated December 2 and addressed to the Treasurer of the Institute, we received the following gratifying report:

"Sorry I've been so blind as not to enjoy the great engineering advantages of belonging as an active AIME member. I will pay the $40.00 balance at the beginning of 1954 or as soon as possible. Please accept my humble apology."

IT seems that a young geologist was sent out to examine a property which was a potential source of iron and manganese.

Upon arriving at the location and embarking on his examination, he found that there was no iron or manganese in the area.

But following the pattern the geologist returned to his home office and set about preparing a report. The opening sentence of the comprehensive manuscript read: "The minerals of interest on this property are iron and manganese, neither of which are present."

Mining men are peculiarly migratory in their professional life and in these travels find that people tend to be basically the same everywhere.

An old resident was sitting on the bench of a village green when a stranger approached him. After introducing himself, and stating that he thought of settling in the town, he asked, "What kind of people live here?"

"What kind of people were they where you came from?"

"Oh, dreadful!", the stranger answered. "Mean, gossipy, quarrelsome! I was glad to leave the place."

The old man nodded his head, "You'll find the same kind of people here."

THE Minerals Beneficiation Div. holds programs made up of highly scientific data, but their extracurricular activities seem to be of a somewhat dubious nature.

It was noted at their Fall Meeting in Hibbing, Minn. that they will cross the lines of accepted behaviour at almost any point. A very well lettered and easily read sign was placed upon the registration desk which said "Local and out-of-town wives please register here". It just goes to show you can never tell about even your good friends.

Charles M. Cooley

D. C. Jackling

D. C. Jackling

Taconite Beneficiation 1953 Parallels Revolutionary Porphyry Copper Development of 1903

D. C. JACKLING, the father of the porphyry coppers, has been honored for his pioneering in that field. There is another facet to Mr. Jackling's activities, one which now may prove an even greater monument than the big coppers—the story of his venture in taconite beneficiation.

The essence of his porphyry development was mass handling of material. Not alone mining on a large scale, which was done on the Mesabi Range at the turn of the century, but the integration on a previously unknown scope of mining, milling, concentration, and in many cases, of final reduction to metal at the site. This was mass production applied to mining, treatment of a very low grade source material, previously considered submarginal.

Billions of tons of magnetite and hematite were present on the Mesabi Range—ore too low grade to utilize directly, tough ore to drill and handle, tough in the literal sense. Yet, it was known that a high grade concentrate could be made by magnetic separation, after grinding to liberate the magnetite, known in a general way, with none of the details worked out fully. Beneficiation had heretofore never been attempted for such a low priced, basic raw material.

Forty years ago Hayden, Stone & Co. of New York, major financiers of the western porphyry coppers, had this situation drawn to their attention. On June 7, 1913 Mr. Galen L. Stone wrote a letter to Mr. Jackling telling him that Dwight E. Woodbridge of Duluth had the idea of application of Mr. Jackling's low grade copper technique to low grade iron ores of Mesabi Range. Jackling accordingly met with Woodbridge later, and that was the start of Mesabi Iron Co., the beginning of the taconites. Mr. Robert G. Stone, son of Galen L. Stone, is and has been for years a director of the Mesabi Iron Co.

By 1915 a syndicate was formed by Mr. Jackling with Hayden, Stone & Co. to explore these possibilities. Studies under the direction of Mr. W. G. Swart went ahead on the geology of the deposits, on magnetic concentration, and on the economic factors of the whole project. Every operation in any way comparable was studied and its costs analyzed.

Experimental ore dressing work went ahead under E. W. Davis at the Minnesota School of Mines Experiment Station and in 1916 a 100-ton plant was erected at Duluth. In 1918 work had progressed to the point that a shipload of experimental sinter went to Midvale Steel & Ordinance Co. to meet special specifications for steel for making armor plate.

Then in 1919 Mesabi Iron Co. was organized with three million capital to finance the building of a plant at Babbitt, Minn. Work at Babbitt went ahead and in July 1922 the first sinter was produced. By 1923 production was 20,000 tons of sinter averaging 63 pct iron; by June 1924 when the price of iron ore dropped, closing the enterprise, half a million tons of taconite had been mined and 150,000 tons of 62 pct iron sinter had been shipped.

What has been written so far is not history—far from it—it is the story of the first phase of the development of the present-day taconite operations. Today Reserve Mining Co. is leasing the lands of the Mesabi Iron Co. In the pioneer plant at Babbitt modern machines are running at pilot plant scale of 3000 tons per day treating the ore from Jackling's original open pit.

This second phase began in 1953—a lapse of almost 30 years. Normally development of an idea follows a more rapid schedule, but here is one not a decade, but a third of a century ahead of its times.

The third and final phase will be the operation of the Reserve Mining Co.'s huge treatment plant at Beaver Bay, 47 miles distant, now under construction.

What has happened to the original judgment of the men who chose the Babbitt property, worked out a treatment scheme, and built that first plant? In essence the ideas are unchanged, the flowsheet reflects surprisingly few changes. But what of the deposit? There are many areas of magnetic taconite on the Mesabi Range, and the opinion of many observers is that Reserve Mining Co. in choosing the holdings of the Mesabi Iron Co. obtained the "cream" of the taconites.

What more can one add—simply that the foresight and courage of one man, measured by today's events was not only sweeping in the grasp of the whole—but penetrating in the analysis of detail and development of the method of execution. Here is growing what D. C. Jackling himself considers may be his greatest mining monument, the beneficiation and utilization of low grade iron ores, the taconites.

Oliver Iron Mining Div.'s Extaca plant located near Virginia, Minn.

Nodulizing Iron Ores and Concentrates At Extaca

by R. L. Bennett, R. E. Hagen, and M. V. Mielke

Oliver Iron's experimental kiln at the Extaca plant provides data on agglomeration of high grade ore fines and taconite concentrates.

FINE IRON ORES, *and concentrates such as those produced from taconite, must be converted to lump form by some process of agglomeration before they can be used effectively in the blast furnace or open hearth. At the present time, four major processes for agglomerating these materials are being used on a commercial scale: sintering, nodulizing, pelletizing and briquetting.*

IN 1945 U. S. Steel Corp. through its subsidiary the Oliver Iron Mining Div., drew up tentative plans for an agglomerating plant on the Mesabi Range which would include a nodulizing kiln and a sintering machine. The purpose of the plant was twofold: during its initial operation it would provide data on agglomeration of high grade ore fines, and would help relieve the shortage of ore for open hearth charging. Subsequently, it would be available for agglomerating taconite concentrates. While operating on fines screened from direct ore, it was planned to develop techniques and personnel so that a workable plant would be ready to handle taconite concentrates when the time came.

A number of features were incorporated in the design of the Virginia kiln, on the premise that they might overcome, to some extent, the undesirable aspects of previous nodulizing installations. A long kiln of large diameter was stipulated to attain maximum heat transfer and consequent fuel saving. A boring bar was provided, to remove ring formation and lining from the last 20 ft of the kiln. To implement the basic conception of restricting the nodulizing zone to a minimum length—within the range of the boring bar, if possible—two burners were specified: the main burner was designed to handle about 75 pct of the fuel, and to burn it as a long lazy flame extending up the center of the kiln for about one quarter of its length; the auxiliary burner was designed to give short torch-like flame directed on the charge near the firing end. A cooler was provided for the kiln discharge, both to cool the product, and to provide high temperature secondary air for combustion, thereby effecting some further fuel saving, and helping to confine combustion to a shorter zone near the firing end. Extensive instrumentation and automatic controls were provided to permit close observation and control of the process.

The size of the kiln, and the general process design, are based on certain theoretical relationships developed by the Allis-Chalmers Mfg. Co. and presented in a report "A Rotary Kiln Design Formula," by W. J. Matzke, engineering development div. of that company, Aug. 1, 1945. In these derivations, fundamental differential equations were set up to express the rate of heat transfer from the hot gases to the charge in the kiln. From these, general form-

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ulae were developed on a purely theoretical basis which relate kiln length, diameter, production rate, stack-gas temperature, and fuel consumption. Terms in the equations may be substituted by numerical values which express nodulizing temperature, secondary air temperature, type of fuel used, percent filling of the kiln, chemical and thermal properties of the ore, etc.

For the case of nodulizing hematite ore of specified analysis at 2300°F, assuming secondary air temperature at 750°F; 10 pct excess air for combustion; kiln 13 pct filled with charge; countercurrent firing of a specified type of pulverized coal, the final equation is:

$$\frac{LD}{W} \quad \frac{(939 + 0.081T)(3491 - 0.1424T^{1.21})}{T^{1.21}(4244 - T)}$$

where L = kiln length (ft)
D = kiln diameter (inside—ft)
W = production rate (long tons nodules per day)
T = kiln exit gas temperature °F.

Although the form of this equation is general for any kiln, the constants given apply only for a particular kiln, operated under the conditions cited. The graph of this equation shows production rate vs exit gas temperature for kilns of 10.5 ft ID, and lengths of 250, 300, and 350 ft. Superimposed on this graph is the theoretical fuel consumption vs exit gas temperature.

Based on these calculations, it was decided to plan a kiln 10.5 ft ID and 350 ft long, with a designed capacity of 1000 tons per day of nodules. A site was selected adjacent to the Rouchleau crushing and screening plant, since this plant could supply fine high grade hematite ore feed at the required rate.

Solid feed materials pass through the kiln, where they are heated and become nodulized. The nodulized product then passes over the grates of a cooler into product handling and loading equipment. Cold air is blown upward through the bed on the cooler grates, and becomes heated. This hot air above the feed end of the cooler is drawn into the kiln for secondary combustion air. Air from the rest of the cooler is vented to the atmosphere through the cooler vent stack. The volume of air drawn into the kiln from the cooler depends almost entirely on the positioning of the kiln exhaust damper; whereas the damper in the cooler stack controls the pressure above the cooler grates and in the kiln hood, and has little effect on the flow of hot air into the kiln. It should be noted that there is no partition above the cooler grates to separate these two air flows. Control of this point-of-no-flow is entirely by damper setting.

Hot air is drawn from the top of the kiln hood as primary air for the air-swept coal pulverizer. The stream of pulverized coal and air discharged from the pulverizer is concentrated and separated by a cyclone splitter into a rich coal-air mixture for the main burner, and a lean coal-air mixture for the auxiliary burner.

Inasmuch as the plant was to be used for experimentation, the original flowsheet included several features which are not used now, and which are not shown on the diagram. Facilities were provided, for example, to return screened nodule fines to the feed end of the kiln; to mix ore, returns, and limestone in pug mills before feeding to the kiln; to by-pass

PROCESS DESIGN

In reviewing the published information on nodulizing operations, certain features appear significant:

1. **Fuel consumptions are reported which vary from 2 to 4 million Btu per ton of product.**
2. **The formation of rings and large balls has been a serious operating problem at all installations during some period of their operation and appears to be the most frequent cause of shutdowns. At some plants, the difficulties associated with ring formation have never been overcome.**
3. **Many operations were initiated as emergency wartime measures to help relieve a shortage of open hearth charge ore. As such, they made use of existing cement plants, which were not necessarily designed for efficient nodulizing of iron ores.**
4. **The addition of fine limestone, in amounts up to 10 pct of the charge, is considered beneficial in lowering nodulizing temperature and lessening ring formation.**
5. **The product quality appears satisfactory, as judged by published screen analyses, and wartime acceptance of nodules for open hearth use.**

Historical Background

Before Extaca was constructed, fine iron-bearing materials had been nodulized at various places throughout the world. According to Gilbert Seil, *Iron Age*, April 27, 1944, p. 40-46, one of the first installations in the U. S. was in South Chicago, where flue dust was nodulized in a 6x60 ft kiln about 1904. **H. Berg**, *E&MJ*, Aug. 1940, p. 56-58, and **S. G. Thyrre** *Steel*, July 5, 1943, p. 116, published data on the work of the F. L. Smidth Co. **F. L. Toy** at the Open Hearth Conference, AIME, 1943, reported on the production of nodules at the Universal Atlas Cement Plant, Universal, Pa., where 10 kilns were in operation in 1942. More recently, data have been presented by **W. E. Simons**, *Jour. Iron & Steel Inst.*, London, Jan. 1951, p. 1-8, on the operation of a 200 ft Smidth kiln at Cardiff, Wales, which is constructed of sections of different diameters. The largest section, near the firing end, is 12 ft 8 in. ID.

Some Definitions

In sintering, fine material is mixed with pulverized fuel and placed on a grate, where the mixture is burned to a clinker under forced draft. *In nodulizing*, fine material moving through a rotary kiln becomes agglomerated into lumps by the rolling of the charge at temperatures near the fusion point. *In pelletizing*, fine damp material is formed into balls in a revolving cylinder, without heating, and the balls are subsequently hardened by heating in a shaft furnace or on a moving grate. *In briquetting*, material is mixed with binders, such as cement, and molded under pressure into briquettes.

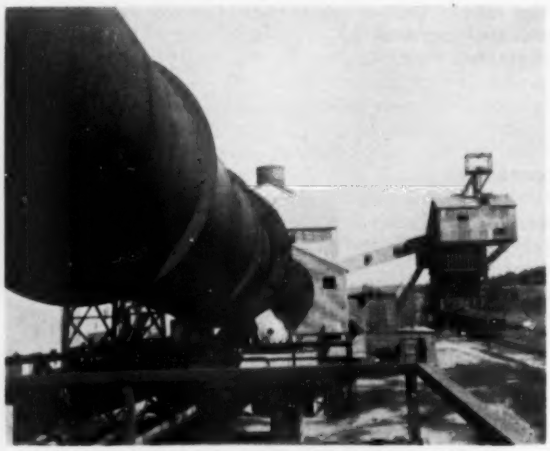
primary air around the coal pulverizer; and to add excess primary air to the auxiliary burner pipe. All of these facilities have been tested, and have not been found beneficial.

Plant Equipment

The rotary kiln, 11 ft 6 in. OD and 350 ft long, built by Allis-Chalmers Mfg. Co., is supported on five piers at a slope of ½ in. per ft, and is driven from the center pier by two 125-hp dc motors through two helical pinion drives at speeds from 0 to 80 rph. A LeRoi 4-cylinder, 47½ hp gas engine serves as a standby unit to turn the kiln in case of power failures or electrical troubles with the regular drive motors. The shell is an all-welded steel construction lined with 6-in. firebrick except for 50 ft at the firing end, which is lined with 9-in. brick. Inside diameters are 10½ and 10 ft respectively. Superduty dry-press fireclay kiln block is used in the fire end where resistance to spalling and a more refractory lining is required by higher temperatures. At the feed end, where abrasion is the prime problem, dense stiff-mud fireclay kiln block is used. The chrome alloy nose ring at the kiln discharge end is cooled by air supplied from the cooler fan. The temperatures of the charge at four points along the kiln are measured by thermocouples protruding through the kiln lining. Ray-o-tube radiation pyrometers are sighted through holes near the top and bottom of the hood to detect the lining temperatures in the combustion zone, and the temperature of the nodulized product.

The Fuller cooler, which takes the hot nodules at approximately 2400°F, from the kiln, is an inclined grate, 8x80-ft, two-stage cooler, made up of two sections in tandem with 20 movable and 20 stationary grates in each section. Nodules are pushed stepwise down the incline, by the reciprocating movement of alternate grates. The hot nodules from the kiln first fall on a water-cooled feed chute, then pass over several water-cooled grates in series before moving on to the perforated air-quenched grates. Three types of air-cooled grates are used from the feed to discharge end of the cooler; namely stainless steel, hard-surfaced carbon steel, and white cast-iron grates. The latter type have partially been replaced by ductile iron and pig mold cast iron grates. Side plates made from ductile iron have stood up well in the hottest parts of the cooler. A Sturtevant Turbovane fan moving 49,700 cfm of air at 9-in. static pressure driven by a 100-hp motor is used on the first section, while a similar type fan on the second section driven by 125-hp motor produces 70,415 cfm of air at 8-in. static pressure. The amount of cooling air moving through the bed is determined by the permeability and the depth of bed, the latter being dependent on the amount of feed from the kiln and the rate that the nodules are moved through the cooler.

Cooled nodules are fed over a 6-in. grizzly. Oversize is crushed −6 in. by an 18x30-in. jaw crusher and the grizzly undersize joins the crusher product, dropping into the nodule bin as finished product. In the course of travel through the cooler and into the bin, nodules have dropped approximately 60 ft below ground level. From this point, an automatic skip hoist built by Bartlett & Snow Co. elevates the nodules to the railroad loading pocket. A counterweight control actuated by the weight of the load energizes the skip hoist drive when sufficient weight of nodules have accumulated in the 90-cu ft skip bucket. When the skip is hoisted, it closes the bin chute, and after discharging the nodules in the loading pocket, the return skip reopens the bin chute as it comes to rest under the nodule bin.



After eliminating many mechanical problems, kiln runs increased progressively to 66 consecutive days of operation which was terminated the middle of May, eight months after the plant was started.

A portion of the heated air from the feed end of the cooler is used in the Babcock & Wilcox E-50 coal pulverizer to dry the coal. This hot air is drawn off at the top of the kiln fire hood and blown into the pulverizer at controlled temperatures by the primary air fan driven by a 125-hp motor. Coal, ground fine enough to be carried by the air stream, is blown into the burner pipes. The temperature of the air-coal mixture leaving the pulverizer is automatically controlled at 150°F. The rate at which coal is fed to the pulverizer is automatically controlled by the rate of air flow through the pulverizer, and there is provision to set the pulverizer control system to maintain various air-coal ratios.

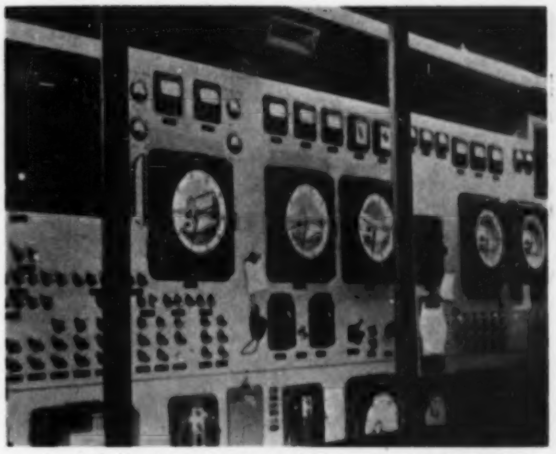
The amount of air in the burner mixture is about 30 pct of the air theoretically required for combustion of the coal in the kiln. The additional air required for the combustion is the preheated secondary air from the cooler induced into the kiln by a two-speed Sturtevant kiln exhaust fan, which is capable of moving 150,000 cfm of exit gases at 800°F and 4.4-in. static pressure. The fan was designed to operate at 710 rpm, and is driven by a 250-hp motor. Exit gas from the kiln rarely exceeds 580°F and consequently it is not necessary to temper the gases ahead of the Buell dust collectors, nor has there been any concern about heat at the fan or water-cooled fan bearings.

Early operation disclosed that the boring bar was necessary in removing kiln rings. It was found, however, that even under the most favorable conditions, the ring formation still extended 5 to 10 ft beyond the reach of the bar. Consequently, it was lengthened, and its carriage rebuilt to carry 50-ft of 20-in. diam tube with 1⅛-in. wall thickness. With this extended bar, the kiln can be bored for a distance of 28 ft from the nose ring. The present boring bar is equipped with a hard-surfaced cutting tool, which is cooled by water through a 4-in. pipe extending along the axis of the bar. Return water flows back along the bar, thus cooling the tube.

All major items of process equipment may be operated manually or automatically by Leeds & Northrup electric controls located on a single master-control panel. Ore feed control, as well as dampers

in the cooler vent stack and in all tempering air ducts, are operated automatically at all times. A considerable number of other instruments are located on the control panel either to indicate or record pressures at several points in the kiln and cooler, the current drawn by drive motors, power drawn by the coal pulverizer, damper positions, temperatures along the length of the kiln, etc.

The nodulizing plant is operated by five men and a plant foreman on each shift. Operation is completely controlled from the master control panel on the burner floor by the kiln burnerman assisted by a helper. The table feederman is responsible for keeping the ore and limestone feeding from the bins properly, and chutes and conveyor belts functioning. The kiln feederman watches the dust collection system, kiln exhaust fan, and ore feeding to the kiln. The coolerman is responsible for the operation of the nodule crusher, cooler grate and screw conveyor drives, fans, and nodule bin and skip.

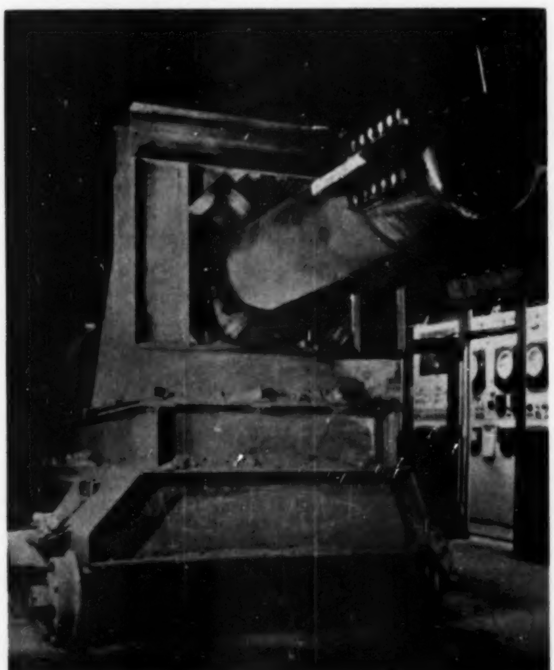


Leeds & Northrup manufactured the master-control panel which operates all major items of process equipment either manually or automatically.

Early Problems

Cold weather conditions soon added to the problems, as the plant building was not insulated nor the equipment winterized. As a result, the operators were confronted for the first 7 months with such problems as frozen ore, limestone, and coal, frozen water and air lines, sluggish operation of equipment and controls in addition to the customary mechanical *bugs* and necessary alterations. Plant winterizing, started in December 1951, included insulating the walls of the raw materials building and conveyor galleries, installation of hot air furnaces and ducts, covers over louvers, and immersion heaters for equipment drives. Severe weather also hampered mining operations in the open pit and screening in the crushing plant. It was necessary to steam much of the frozen coal and limestone received in railroad cars. Until the coal bin was insulated and a coal crusher added ahead of the bin it was practically impossible to control the rate at which coal was fed to the pulverizer. In addition to immersion heaters on the gear reducers and kiln girth gear, heated transformer oil was circulated through the kiln exhaust-fan bearings and kiln carrying-roll housings. Before the second winter's operation, the kiln drive was housed.

In removing kiln rings, a boring bar 50 ft long of 20-in. diam with a 1⅛-in. wall thickness is used.



A series of changes were made to the coal firing system before satisfactory burning was obtained. The original two-burner arrangement consisted of a 17-in. diam main burner nozzle and a 12-in. diam water-cooled auxiliary burner nozzle with the pulverized coal-air mixture distributed by a cyclone coal splitter to the two burners. To maintain sufficient air velocities in the burner pipes at nominal coal rates it was necessary to carry large air volumes resulting in high air-to-coal ratios in the mixture. The result was a short torch-like burner flame that caused localized heating of the kiln lining and eventually ring formations. In addition, infiltration of cold air to the kiln from around the hood and through uncovered cooler grates contributed to inefficient combustion.

Considerable improvement resulted after the following changes were made to the burner pipes: the main burner pipe was replaced with a 12-in. pipe and 10-in. burner nozzle, made from stainless steel and insulated with plastic refractory. The auxiliary burner was replaced with an 8-in. nozzle fabricated like the main burner.

In the course of time, techniques were developed whereby a lazy flame, 60 to 80 ft long, could be maintained at the main burner, while a torch-like flame from the auxiliary burner was directed on the charge. This result was secured by simultaneous control of coal-air ratios in the two burner pipes, while controlling the distribution of coal between the burners with a gate in the main burner line.

Early operation was necessarily one of trial and error, with every error carrying such penalties as melted burner pipes when burner line velocities dropped low enough to allow coking, or formation of rings when intense localized heat was directed too far up the kiln. Needless to say, the early runs were numerous, and of short duration, and had to be terminated in practically every case by a complete shutdown to remove ring formation.

OPERATING STATISTICS

Results of 53-day run, April 18 to June 10, 1953, treating Group 3 fines and a 3-day test, June 30 to July 3, 1953, treating magnetite concentrate.

Optimum nodulizing temperature (Ray-o-tube indication)	2300 to 2380°F high silica ore (over 8 pct) 2450 to 2500°F low silica ore (under 4 pct) 2300 to 2350°F Magnetite	
Temperature 102 ft from nose brick No. 3 thermocouple	900 to 1100°F	
Temperature 177 ft from nose brick No. 2 thermocouple	340 to 450°F	
Temperature 253 ft from nose brick No. 1 thermocouple	50°F	
Secondary air temperature	about 1400°F	
Kiln exit gas temperature	530 to 580°F	
Cooler vent stack gas temperature	150 to 300°F	
Temperature coal-air stream at pulverizer discharge	150°F	
Temperature nodules discharged from cooler	70 to 300°F	
Kiln hood pressure	—0.03 in. water gage	
Pressure under cooler grates	No. 1 cooler 6 to 9 in. water gage No. 2 cooler 4 to 6 in. water gage	
Oxygen in kiln exit gas	1 to 2 pct—Group 3 2 to 3.5 pct—Magnetite	
Kiln speed	67 rev. per hr	
Average ore feed rate, long tons per hr, dry	44.1 47.4	Group 3 Magnetite
Percent limestone in feed, dry	4.06 4.00	Group 3 Magnetite
Average nodule production rate long tons per hr, dry	42.4 45.8	Group 3 Magnetite
Coal consumption per long ton nodules, lb	175.66 133.92	Group 3 Magnetite
Heat value of coal Btu per lb	13,666 13,782	Group 3 Magnetite
Fuel consumption Btu per ton nodules	2,400,532 1,846,000	Group 3 Magnetite
Kwh per ton of nodules avg	16.2	

Typical Sieve Analyses

	Cumulative Pct Retained	
	Kiln Feed for Group 3	Nodule Product
+ 2 in.	—	2 to 3
+ 1½ in.	—	35 to 45
+ 10 mesh	20 to 30	92 to 95

Taconite concentrate fed to kiln is approximately 80 pct —200 mesh

Chemical Analyses of Nodulized Product, Avg

	From Group 3 Ore Pct	From Taconite Concentrate Pct
Moisture	0.16	0.12
Fe	63.23	62.99
SiO_2	5.63	7.33
Mn	0.34	0.29
Phos	0.054	0.020
CaO	2.19	2.44

The rapid and uncontrollable formation of rings —some extending 70 ft up the kiln—was one of the most serious problems of the first 7 months operation. During this stage, use of a kiln gun—an 8-gage shotgun firing a 2½ oz lead slug—was moderately successful in breaking up rings, and in dropping heavy lining beyond the 20-ft boring bar.

The formation of such unmanageable rings can now be ascribed to poor flame qualities, interrupted coal and ore feeding aggravated by sub-zero weather, and to the rapid changes that were made in fuel rates and damper settings. With these fluctuating conditions, large masses of plastic lining adhering to the brick in the 20 to 40-ft zone would frequently drop and soon snowball into large balls, if obstructed from coming out of the kiln by even a slight ring formation. Such large balls, often several ft diam and weighing up to 5 tons, impeded the flow of solids and combustion gases, and damaged the brickwork if allowed to roll in the kiln for any length of time.

By the spring of 1952, warmer weather, and elimination of many mechanical problems, resulted in a decrease in the number of process interruptions. At the same time, the operators became more experienced and learned to recognize and correct for slight changes in operating conditions by making minor adjustments. Kiln runs increased progressively in length, up to one of 66 consecutive days of operation, which was terminated the middle of May —8 months after the plant was started.

Present Practice

Following the 66-day run, certain principles have been established which at present are considered fundamental to successful operation. Departure from these principles, by improper operation of the kiln or its major ancillary equipment will eventually result in a condition of temperature instability with all its attendant difficulties: poor product, high fuel consumption, and formation of rings.

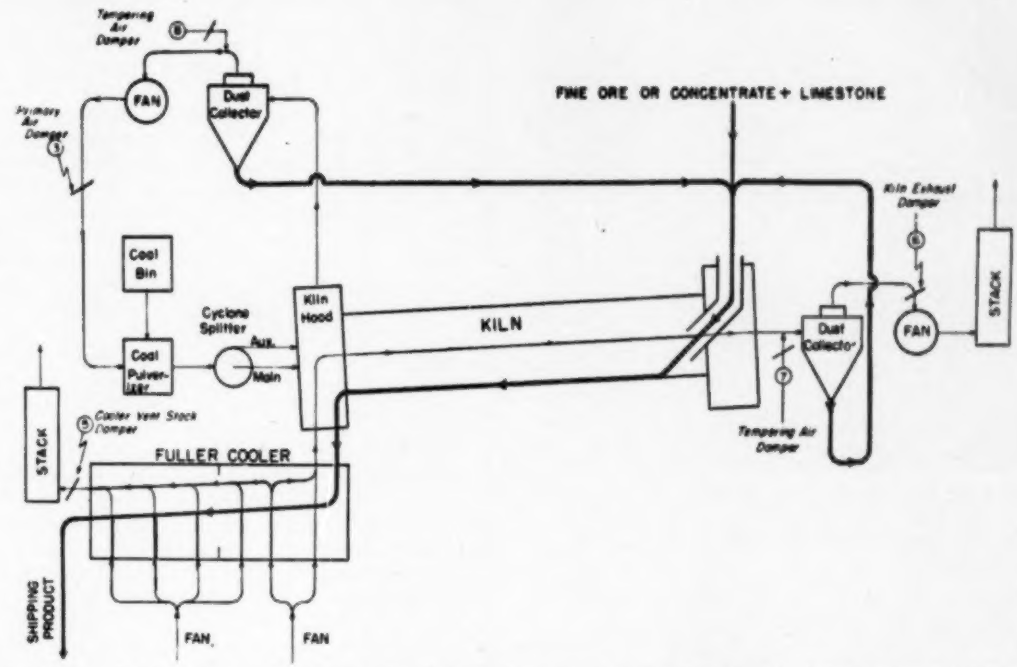
It has been found that the prime requirement of a temperature-stable kiln is most readily attained by holding constant the rate of feed, the kiln speed, and the oxygen content of the stack gas. If this is done, then only minor changes in fuel rate will be required to compensate for variations in quality of feed, or in temperature of air from the cooler.

The following sections outline, in more detail, the principles followed in operating the nodulizing process according to this concept:

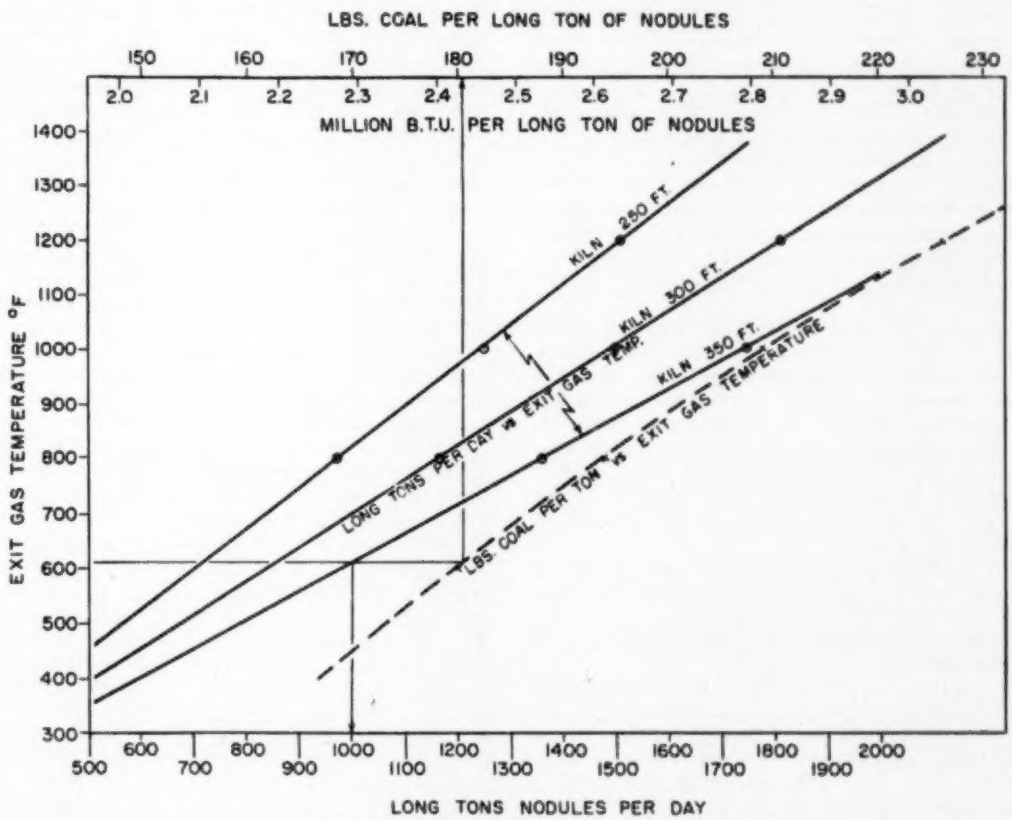
1—The kiln feed of ore fines and limestone is held at the desired rate by control devices which automatically adjust speed of the table feeders to hold a weightometer rateograph combination at the control point.

2—Kiln speed is normally held constant. However, if it must be changed for any reason, such as boring, or to correct major temperature upsets, then the feed rate is also changed to keep a fixed ratio of feed rate to kiln speed. This procedure maintains a constant loading along the length of the kiln and avoids subsequent temperature upsets which would result as light or heavily loaded sections moved into the nodulizing zone. Automatic devices are provided to interlock feed rate and kiln speed, but are not usually employed.

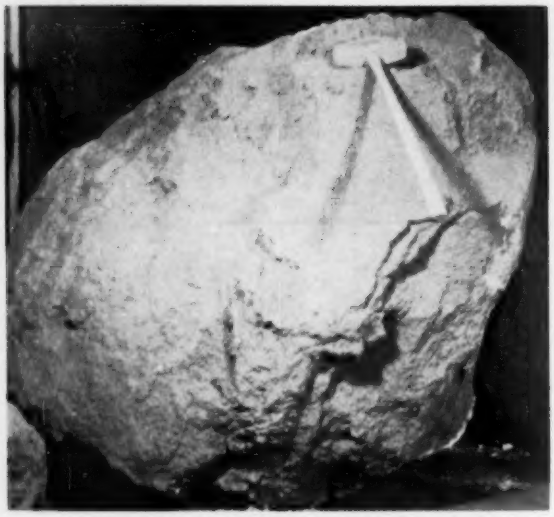
3—The kiln exhaust damper is controlled manually to maintain the oxygen content of the exit gases at 1 to 2 pct, as measured by a continuous oxygen analyzer and recorder.



Solid feed material, shown as a heavy line in the above flowsheet, passes through the kiln where it is heated and nodulized. The nodulized product then passes over the grates of a cooler into product handling equipment.



Production rate vs exit gas temperature is shown for kilns of 10.5 ft ID and lengths of 250, 300, and 350 ft. Superimposed on this graph is the theoretical fuel consumption vs exit gas temperature.



With fluctuating conditions within the kiln, large masses of plastic lining in the 20 to 40-ft zone snowball into large balls. One of these balls is compared with a 16-lb sledge hammer.

4—It would be desirable to maintain constant chemical and screen analysis of the kiln feed. However, a variety of ores are screened at the Rouchleau plant, with no facilities for blending and the screen undersize product may vary in chemical analysis and size distribution. This condition differs considerably from modern cement kiln practice, where feeds can be precisely controlled in blending and storage facilities.

The amount of moisture, water of crystallization, and volatile material in the kiln feed affect the fuel rate and the temperature gradient through the kiln, whereas the amount of silica in the feed and the amount of limestone added affect the optimum temperature in the nodulizing zone. An ore feed which varies greatly in chemical analysis will cause temperature fluctuations of large amplitude and an unstable kiln.

No quantitative data correlating size distribution of feed to kiln operation have been accumulated. However, it has been observed that finer ores and taconite concentrate appear to nodulize better and make a product superior to the coarser ores due to fusion into a strong homogeneous mass. It has been found that the larger particles fuse only on their surfaces and tend to retain their identity in the nodule product, which is usually of poor strength as a result of this action.

It was anticipated that many kiln upsets would be eliminated when treating taconite concentrate because of the uniform quality of the feed, and several short runs on taconite concentrate have proven this to be correct.

With changing quality of feed, the heat input to the kiln must be gradually changed. Thus, the operator must anticipate and correct for temperature changes in the nodulizing zone some 2 hr before they occur. However, no measurement can be made of the changing quality of material entering the kiln which would direct the operator to change the fuel rate. Consequently, the kiln is allowed to seek its own temperature gradient and exit gas temperature, while holding some optimum nodulizing temperature. The attempt is then made to maintain these conditions relatively steady for each particular type of feed, by making a minimum number of small adjustments to the coal rate. No attempt is made to hold predetermined temperatures along the kiln, or at the kiln exhaust.

The fuel rate is controlled manually, according to judgment based on the temperature of the kiln lining near the discharge end, measured by Ray-o-tube, and on temperatures measured by thermocouples at 4 points along the length of the kiln. The latter are recorded to permit the trends to be followed.

Some control of heat distribution in the kiln is available to the operator, since opening the exhaust damper has the immediate effect of heating up the feed end of the kiln.

5—The cooler grate speed is controlled manually, according to judgment based on undergrate pressure, depth and nature of the bed. The function of the cooler is twofold: a) to discharge a product cool enough to be handled in bins, skip, and railroad cars without damaging them, and b) to recuperate the maximum amount of heat at the highest intensity possible. Under ideal operation, the secondary air recuperated from the cooler should remain constant in volume and temperature, for any given rate of coal firing. The most efficient cooler operation is attained when the nodule product is of good quality. If the product is fine as a result of a temperature upset in the kiln, both cooling and heat recovery are poor because of channeling of the air in passing through the bed. At the same time a fritting action may occur in the bed which tends to make it impermeable to the passage of air. In a few instances the fritting has caused such a great pile-up of large chunks at the grizzly oversize chute that the kiln feed rate had to be reduced until the large pieces were disposed of. Generally fritting is associated with fine product and deep bed on the cooler grates, and in most instances can be brought under control by increasing the grate speed, i.e., reducing the bed depth. It is believed that fritting is induced by intimate contact of fine particles, channeling in some parts of the bed and low velocity air flow in others, together with a rise in temperature of the bed in the latter areas as a result of heat given off by the oxidation of the nodules.

6—Kiln hood pressure is maintained at minus 0.03 in. water gage by automatic control of the cooler vent stack damper. A greater negative pressure would result in excessive leakage of cold air into the kiln, and positive pressure would allow hot dust-laden gases to blow out the Ray-o-tube ports and other openings in the kiln hood.

7—The kiln is bored once a shift to remove rings that build up in the nodulizing zone. Unless the kiln speed is reduced during boring, an abnormally heavy load is thrown into the cooler, and secondary air flow and temperature are changed. At the same time, the water-cooled boring bar tends to cool off the kiln. To compensate for these effects, the kiln speed is decreased 10 rph, e.g., from 67 to 57 rph, during the 20-min boring period, the feed rate is cut proportionately, and the coal rate is held substantially constant. This practice results in minimum temperature upset, since the rate of discharge into the cooler remains about constant, and with the slower kiln speed, the kiln temperature tends to rise to balance the cooling effect of the boring operation.

Mining Trends on the Mesabi Range —

More Stripping—Truck Pits—Conveyors

BETTER MINING METHODS *have kept pace with demands for iron ore by opening more small mines, and by making open pit operations out of old underground properties. Efficient, flexible transportation is a vital step as trucks and conveyors are chosen to deliver ore to improved concentration plants. Large taconite pits, big tonnage, and long hauls bring increased importance to rail haulage which has been taking a back seat to the truck-conveyor system. Tough taconite ore has already spurred advances in drilling techniques and equipment.*

by B. M. Andreas

PRIOR to 1934 all haulage of ore and stripping on the Mesabi Range was by rail. Early rail systems had small narrow-gage locomotives with correspondingly small dump cars. These trains were replaced with larger standard gage rail systems powered by steam locomotives ranging up to 224 tons in weight, which have in turn been replaced by diesel electric locomotives. Along with this development cars have been increased to 30-cu yd capacity. Improvement of cars includes alloy steel construction for lower over-all weight and use of roller bearings to decrease rolling resistance.

Despite all of these developments, the total material hauled by rail on the Mesabi Range has decreased every year. Yet, this is no reason to believe that rail haulage is becoming obsolete. Its adaptation to small mine operation has become impractical, but in large mines where normal railroad grades are possible or where hauls to plants or dumps are long, rail haulage is still one of the most economical methods of transporting large quantities of material.

With the development of taconite mining, there is a general belief that the percentage of material to be hauled over rail systems might increase. Taconite operations must be large scale. Big pits, large tonnages, and in some cases long hauls, will mean more tonnage hauled by rail.

Many small mines have been developed in the past 15 years; mines that could not be operated with a rail haulage system, mines that were considered future underground operations. Limits on grade and curves that a train can operate over made it impossible to establish rail systems to the depth required with small areas without increasing stripping ratios beyond the economic limit. Development of truck haulage met this problem.

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Large draglines in stripping operations in northern Minnesota have been the most spectacular development in loading in the past few years. An advantage of these draglines is the long boom, that gives the machine a large working area from one position, as well as the ability to excavate cuts up to 100 ft deep.

First record of the use of trucks to transport ore on the Mesabi Range dates back to 1933. These trucks were the small standard 2 to 4-cu yd dump trucks which were loaded by small shovels in scramming projects.

Truck Haulage

The real beginning of heavy truck haulage on the Mesabi Range was in 1937 when 15-ton capacity units designed for the conditions were introduced. During this first year trucks moved only about 2 pct of the total ore shipped from the open pit mines in Minnesota, but by the end of 1945, this percentage increased to 50 pct of all open pit ore shipped and 68 pct of all stripping material moved. In 1951, 64 pct of the 74.5 million tons of iron ore and 84 pct of the 104 million cu yd of stripping were moved by trucks.

During this period of truck development, design has improved immensely. First trucks were of 15-ton capacity with 150-hp engines. In 1944, the 22-ton truck with a 275-hp engine was introduced and soon became the standard size for most companies. In 1948, the 34-ton truck with tandem rear axles was introduced and at present, the 34-ton unit is replacing the 22-ton truck as standard equipment. These latest models are powered by two 200-hp or one 400-hp engine, depending on the operator's preference. Today an experimental model of a 50-ton truck, similar in design to the 34-ton truck, is on the range. Forty-two of these trucks are now being used in other parts of the country.

Since the development of taconite as a positive source of iron ore, it is considered poor policy to deposit stripping within some limits of the iron formation. This means longer hauls from truck-operated pits will invite the use of larger trucks, probably of 50-ton capacity.

Along with the development of larger engines, mechanical details are constantly being improved, and the most important development probably has been the adaption of torque converters and semi-automatic transmissions to these heavy haulage units. Torque converters and improved transmissions make for easier operation and better performance of the truck as well as for reduced maintenance of the power units and the power train. Other improvements include power steering, air clutches, larger hoist jacks, improved tires, thermostatically controlled radiator shutters and fans, and exhaust heated truck boxes.

Belt Conveyors Have a Role

Trucks are not as efficient for elevating material as they are for horizontal transportation, and to overcome this handicap, belt conveyors have been adapted to open pit mining. Belt conveyors are capable of carrying material up to 30 pct grades with a pay load amounting to about 95 pct.

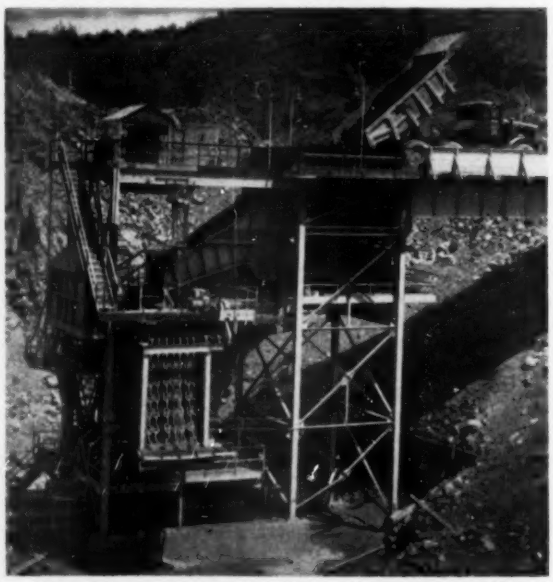
The first belt conveyor system for mining in 1934 transported ore from loading chutes in an underground mine to the bottom of an adjacent open pit and from there to the surface. Since 1936 the use of conveyor belts has increased rapidly and belts in use vary from 18 to 60 in., with the 30 and 36-in. widths the most common. Belt speeds vary from 200 to 650 fpm. In the past few years application of conveyor belt haulage has been extended to stripping. This use for stripping has developed slowly due to two facts: most stripping dumps are necessarily located far from the mine; and second, during the winter when most stripping is done, belts cannot be operated normally without being heated. The cost of construction of conveyor galleries to permit heating, as well as the cost of heating, has not been practical.

One of the big improvements in conveyor systems is the high-tension belt, one of which often eliminates several transfer points from the system.

The conveyor is ordinarily only one link in the haulage system. Usually trucks dump their load at a centralized belt loading point which has a screening plant to control size of material to that which the belt can handle. The belt delivers the load direct to a treatment plant or to a bin where ore cars or dump cars are loaded.

For maximum grades, hoisting skips up the side of the open pit surpasses the conveyor belt. On the Mesabi this method was heretofore confined to underground mining, but today hoists with up to 20-ton skips are being used in deep and confined pits where conveyors would be impractical.

In other parts of the country there are installations where crude ore of much lower specific gravity than iron ore is pumped from the mine to the plant.



One of the most common combinations uses shovels, trucks, crushing and screening plant, and a conveyor belt for loading into bins or for transportation to the concentrating plant. Typical screening and truck dumping point is shown.

Pumping of crude iron ore has been tried on the Mesabi Range but to date has not been found economical. In the past two or three years the trend in reclaiming fine tailing from ponds for retreatment is dragline loading into a portable screening plant, then pulping and pumping the material to the treatment plant. This has been found more flexible than the use of a portable screen plant with conveyor haulage to the plant.

Matching Equipment

No matter what haulage system is used, it can transport only as much material as the shovel or dragline can dig. Because of the number of men required for truck haulage, proper mating of loading and haulage is necessary to maintain efficiency and to eliminate having men and equipment stand idle. To make possible efficient loading of various sized trucks, various shovel models have been developed, with those most used ranging from 2½ to 10-yd capacity. Practically all shovels of 4-yd capacity or more are electrically operated. Electric shovel performance has been improved with modifications of the standard Ward-Leonard control, and the smaller gasoline or diesel shovels are being improved by use of torque converters.

Introduction of large draglines in stripping operations in northern Minnesota has probably been the most spectacular development in loading during the past few years. Large draglines have been common in other parts of the country for some time, their prime function being to cast overburden or stripping in coal mining operations, and for constructing ditches and dikes. One of the features of the large dragline with 180-ft boom is its ability to excavate a cut 90 to 100 ft deep and to hoist and dump its load into a portable screening plant or a large truck. Combined excavating and hoisting eliminates 900 to 1000 ft of truck haul on a 10-pct grade. Bucket capacities of these draglines vary from 6 to 30 cu yd. Haulage from a large dragline at the present time has been confined to trucks or conveyor systems.

Trucking roads, screening plant, conveyor belt and treatment plant are shown in their relative positions, pointing out the advantages of this combination of units. Reduction of upgrade hauls for loaded trucks is one outstanding gain.

Three vital open pit machines, churn drill, 8-cu yd shovel, and 34-cu yd truck to give low cost production. Matching size of units to minimize delays is key to successful operation.

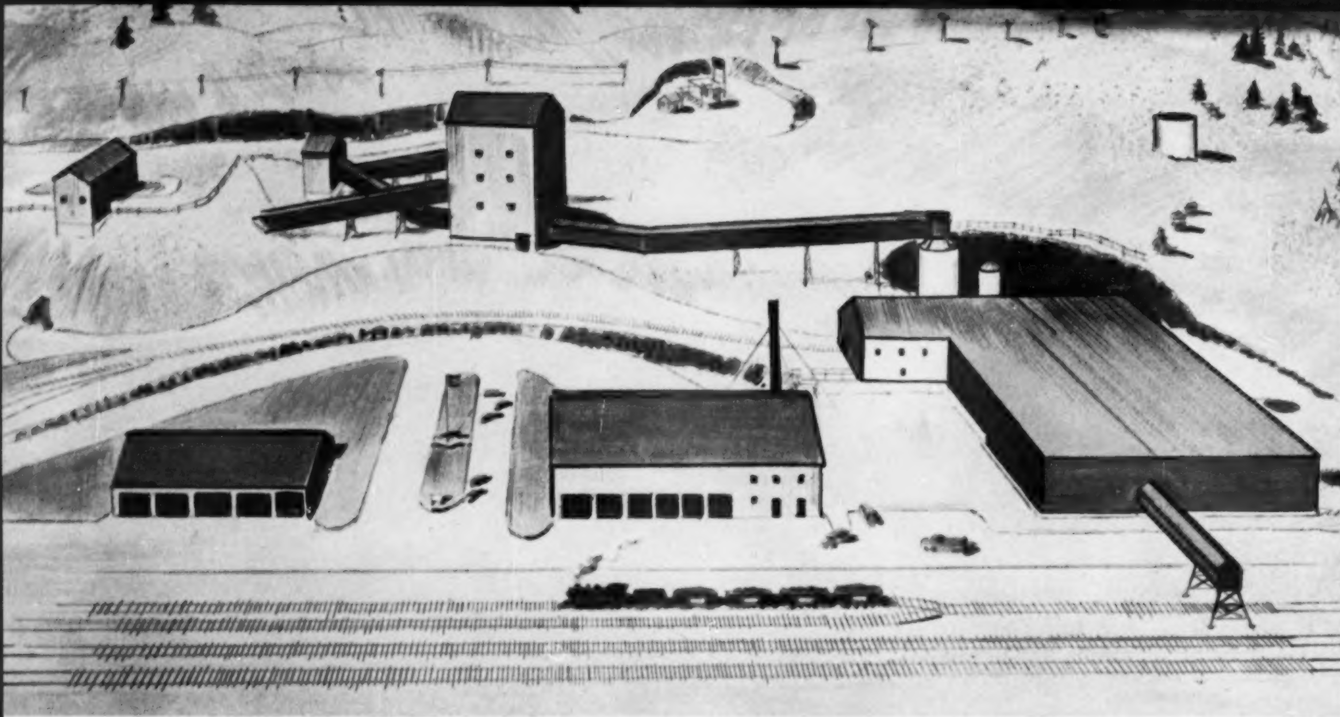
In winter when conveyors cannot be operated, trucks are often substituted, though under normal conditions, the dragline-conveyor combination is more efficient than dragline-truck operation.

The combination of loading and hauling equipment most used today is the shovel, truck, screening plant, and a conveyor which discharges material into bins for loading of cars or for treatment in a concentrating plant. This method takes advantage of the truck's mobility in the pit bottom and the conveyor's ability to haul up steep grades. When a concentrating plant is necessarily located at some distance from the pit, rail haulage between the belt and the plant is sometimes used. In some cases plants have recently been moved closer to the mine to eliminate the rail haulage. In large open pit mines where rail haulage from the shovel is normal, trucks are often used between the shovel and the train when cleaning up irregular pit bottoms. In small open pit mines, truck haulage by itself is often all that is necessary.

For many years 6-in. churn drills were used. In the past 10 years these drills have been improved and enlarged to drill 12-in. holes to yield lower drilling and blasting costs. By using larger holes, fewer are required.

With the advent of actual taconite mining, it became necessary to develop drills of greater capacity and efficiency. The most revolutionary development has been jet piercing. The machine, using fuel, oxygen, and water, partially fuses and heats the material which when quenched with water spalls and is blown out of the hole by the gases developed. Another development is the pneumatic-percussion drill that provides more strokes per minute than a churn drill. This new machine operates on the principle of the old piston drill. The compressed air which operates this drill also blows the cuttings out of the hole. No water is necessary. Another drill uses a hydraulic system to replace the standard walking beam. The rotary type drill, in common use by the oil industry, is the latest type to be tried on taconite.

Today the development of any one mine requires that all types of haulage equipment must be given consideration. During the past few years the availability of materials and equipment necessarily had a large bearing on the choice of type and size of mining equipment to be used. Now, with the increasing availability of material, it will be more possible for the operator to procure mining equipment that will give the most favorable results.



Humboldt iron ore flotation plant located on the Marquette range in Michigan.

Humboldt Mill — Features of Design and Construction

by O. W. Walvoord

ONE particular plant has been chosen to illustrate the various factors in mill design. The problems are general in nature and with various modifications are met in the design of most milling plants. Literature on modern mill design is not extensive and certainly has not kept pace with the rapid advancement in the art of ore beneficiation. Much remains to be investigated, and continued vigilance is required to give the operator and the metallurgist the best layout to meet the industry's changing requirements.

The Humboldt project, a joint venture of the Cleveland-Cliffs Iron Co. and the Ford Motor Co., involves an iron ore flotation plant near the town of Humboldt, on the Marquette range of the Michigan Upper Peninsula. A crushing plant, designed for an ultimate capacity of 720 long tons per hr, is followed by a first mill unit of 70 long tons per hr. Future mill units are planned to bring the total mill capacity to 5000 long tons per 24 hr.

Specific location of the Humboldt mill and crushing plant was chosen with the thought of its access to the mining area, nearness to the railroad, future additions of mill, stockpiling, availability of truck service roads to all buildings, and the combined operational and repair facilities of mine and mill.

Coarse Crushing Plant

Primary crusher and crusher building foundations are set on rock with the only excavation being a bench cut into the hillside. The concrete portion of the structure below the ore truck road will be backfilled with overburden material from the pit. By this method, backfill is substituted for rock excavation, and maximum stability is obtained at a minimum cost.

Ore is received from the pit in 22-ton trucks and provisions have been made for the trucks to drive through the crusher building and over the 48-in. gyrator crusher. This continuous method is preferable to the backing up of trucks, because it permits more loads per truck and is a safety feature.

This method of truck drive-over is achieved by having two horizontal, air operated, movable panels projecting over the crusher and supporting the trucks. With the panels in a receded position, the trucks dump directly into the hopper above the crusher. This feature is not a new idea, having been used on the Iron Range for some time with good results

Other facilities in the coarse crushing plant include a repair bay, elevator, service well, dust collection, and access to the crushing plant from the top as well as the bottom of the structure.

A surge bin is located directly below the crusher and confined within its foundation. An overflow chute with an automatic alarm is to be installed to prevent ore from backing up into the crushing chamber. The surge bin, in this location, not only reduces the head room but also smooths out the trucking operation and removal of crusher eccentric.

A Ross chain feeder is used to regulate the discharge from the surge bin because of its minimum operating and repair troubles. It can be used at this location because the ore is free flowing. A buffer conveyor belt of short length and special design receives the discharge from the chain feeder, minimizes the vertical fall of the ore, and imparts a horizontal velocity to the ore, approximately the

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same as the main conveyor belt on which it discharges. The further purpose of this buffer belt is to absorb the scuffing action that normally occurs at any loading point.

Secondary & Tertiary Crushing Plant

This plant will consist of two crushers, one secondary and one tertiary, with provisions for an additional tertiary crusher to provide increased capacity when future mill units are installed. Each crusher will be preceded by screens for the removal of the fines.

There are no special features, as such, in this plant; the layout being determined by the requirement that all the machinery be in one building. This permits a minimum number of operators, and yet obtains the best control of ore flow. The operating station of the crushing circuit will have console type electrical controls, all interlocked, with each machine visible from this station. A repair bay will be provided with overhead crane. The crushers will operate in open circuit with space allowance provided for close circuiting later.

Particular care and attention has been given to all conveyors in the crushing section, since they involve high starting and operating tensions. All conveyors will be provided with automatic *stepped type* starting controllers, carefully calculated to prevent exceeding the allowable belt tension for no-load, part-load, and full-load conditions as well as to prevent lifting the belt off the idlers in the vertical curve section. Other conveyor design features include straight faced, chevron grooved, lagged head, and snub pulleys; graduated idler spacing; vertical gravity take-ups; and anti-friction bearings.

Mill

The mill can be termed as of *one-floor operation* with some operating sub-levels below and some above the operating floor. Open type floor grating provides visibility for equipment located below the main floor. The mill flowsheet is conventional in that it has the usual rod and ball mill grinding, classification, cyclones, flotation and filtering sections.

THE PROBLEM is to obtain the lowest possible unit cost of production with the smallest capital expenditure consistent with the best layout and economics of the project. The answer to the problem is not so simple when the many factors that must be assembled are considered.

The factors and items are:

Source of raw material	Foundation Requirements
Transportation Facilities	Type of Construction
Storage	Heating, Ventilation, Dust Collection
Power	Fire Protection
Water	Availability of Materials & Equipment
Tailing Disposal	
Labor-Supply & Housing	

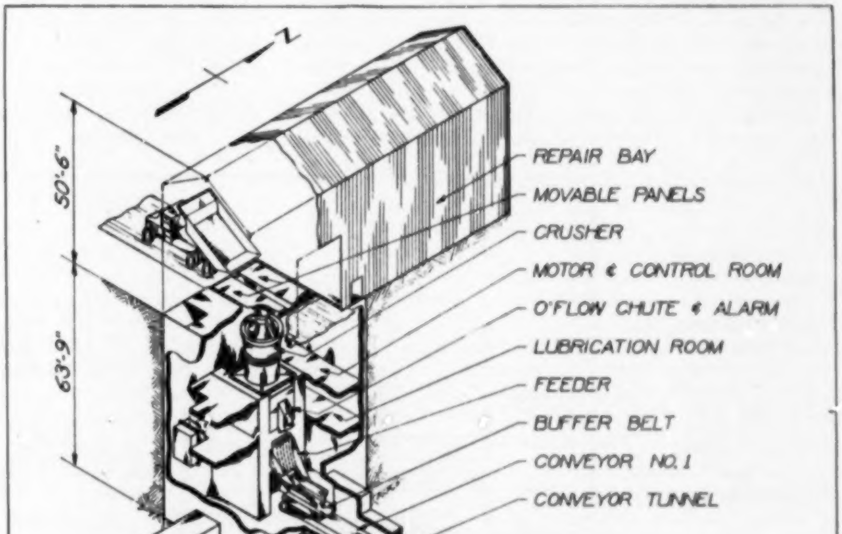
Four feeders located under the steel circular fine ore bin are arranged to operate continuously thus reducing the tendency of feed segregation. Provision is made for two feeders to handle the total tonnage in case of emergency or repairs. One feeder in each line is to have automatic controlled variable speed, actuated from a conveyor scale.

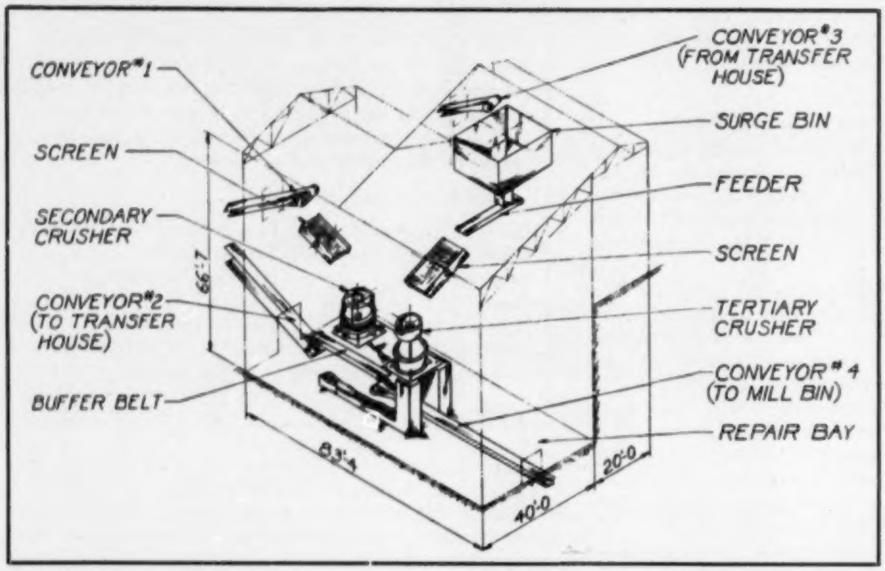
Arrangements have been made in the grinding section to accommodate additions or changes in the grinding circuit if at a later date it is advisable to enlarge the feed to the grinding circuit by eliminating the tertiary crushers. In the flotation section, additional capacity has been provided.

Advantage was taken of the hillside slope for whatever gravity flow of the pulp could be obtained, along with suitable foundation requirements of putting the heavy machinery on rock and yet maintain, as nearly as possible, the one-floor operation.

Electrical disconnects, starters and secondary transformers are mounted on a separate mezzanine floor for a dry and convenient location with push-button control stations located at various places throughout the mill. A red light indicator by each push button will show when the machine is operating. Locking type of push buttons and disconnect

Ore from the pit is delivered to the crusher building in 22-ton trucks which drive over the gyrator crusher.





Layout of the secondary and tertiary crushing plant was made to place all the machinery in one building. This permits a minimum number of operators and yet obtains the best control of ore flow.

switches provide safety for the workmen during electrical maintenance.

Construction

Walls and roofs are to be of what is termed *sandwich type construction*, having two layers of galvanized iron with ample fibre wool insulation between. The inside wall is positioned on the inside of the building girt line, thus making a smooth inside wall which prevents dust collection on the building girts, and for no additional cost gives a neat and pleasing appearance. Windows have been used sparingly to obtain controlled ventilation and yet not give the operators a closed-in feeling.

Wherever possible, the access doors to the various buildings have been located in the gable end of the buildings as a safety measure for protection from falling icicles. As a further precaution the eave cornice will have electrical *hot-bed* wires installed to prevent an excessive ice build-up.

Dust collection is to be of the unit or individual type, located as required and of a design that permits recirculation of air in the building. This reduces heat losses that would otherwise occur from numerous air changes.

Launder slopes are always a problem, and particular care has been given to this phase of the design. Some valuable information was obtained from tests made during pilot plant experimentation. A launder analysis sheet was prepared including product identification, particle size, gpm flow, percent solids, spray water addition, width of launder, and depth of flow.

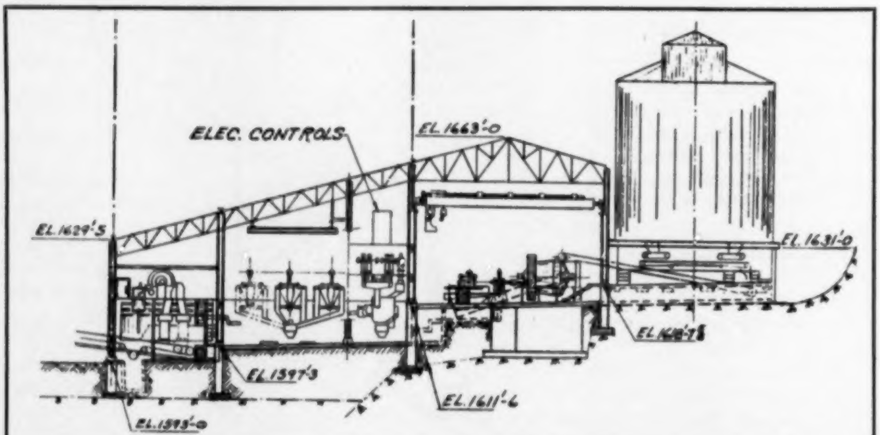
Automatic controls are designed to produce a smooth, steady flow of material, while methods for obtaining metallurgical control are being installed with particular care.

Concrete mill floors are sloped toward the filter section. At the low edge of each floor is a collecting launder, gathering the drainage to a common point and discharging it into a launder in the floor below. By using this method each floor has its own drainage system. Located in the filter floor, which is the lowest, is a sump for returning floor wash either to the circuit or tailing line with provisions for a sump overflow to the outside during power failure.

The floors in the crushing plants and mill have a minimum of pits to better facilitate clean-up and repairs as well as obtain safety. Wherever it was impractical to avoid a pit, a gravity drain was provided for wash-down purposes.

Finally, consideration has been given to the overall architectural appearance of the buildings and their arrangement.

The mill is a one floor operation type with some operating sub-levels below and some above the operating floor. Open floor-grating provides visibility for equipment located below the main floor.



Russian Coal Mining Development

by J. D. A. Morrow

ON Coal's Horizon one development rises above all others. That is the swift expansion of output to make Soviet Russia the largest coal producer on earth next to the United States. Few Americans are aware of the speed and extent of that expansion nor of the accompanying creation of a strong, resourceful mining machinery industry, nor of the extent and character of the mechanization of Soviet coal mining.

Two initial clarifications are necessary for better understanding.

First, we must keep in mind the sharp distinction between the Russian people and the communist Soviet dictators who rule them. The great mass of the Russian people are not members of the Communist Party as people here are Republicans or Democrats. They are not permitted to be members. There are, by various estimates, only 2 to 4 million members of that party in all Soviet Russia. The other 196 to 198 million are the victims of their tyranny and their terror. It is the activity of the Soviet rulers that concerns us here.

Second, understand clearly that the author has no special secret knowledge on this subject. Facts and figures, except as noted, come from published sources that are available to everyone who wishes to read them.*

This article makes use of firsthand knowledge of executives, engineers, and overseas friends to interpret the significance of the Russian coal mining expansion against the background of American and Western European mining accomplishment.

Long wall mining is the system generally used in producing Soviet coal. It is known from Russian publications that long wall mining is employed in the Donets River Basin, called the Donbas, the Moscow Basin mines, and the Kuznetsk field, 2000 miles southeast of Moscow, south and east of the Siberian town of Novosibirsk. The more recently developed Karaganda mines in Kazakhstan are likewise probably long wall, but they may be the scene of room and pillar experiments.

Some coal is obtained from stripping operations, but no specific information as to the extent of such operations nor of the tonnage of coal so produced was obtained.

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In Russia, as in Western Europe and America, coal is a major source of energy and industry. Thus, the increase of coal output signalizes a roughly corresponding rise in industrial potential.

Inspection of production figures reveals the startling fact that in the 25 years from the beginning of the first Five Year Plan to 1952, American and British coal output was stationary, or had declined slightly, while Soviet output in 1952, of 332 million tons, was nearly eight times the 1928 production and was 30 pct greater than Great Britain's production last year. In that quarter century and in the postwar period, the rate of Soviet coal expansion far surpasses that of any other important coal mining country. Furthermore, for 1955 the Soviet rulers plan to push output up to 416 million tons.

Soviet crude steel production presents a similar picture, rising from 19.4 million tons in 1937 to 38.0 million tons in 1952. The current Five Year Plan provides for 48.7 million tons in 1955. Remember that Hitler's Germany was producing only 25 million tons when he started World War II in 1939.

The U.S.S.R. rate of increase in electric power production also outstrips that of the Western European nations and the United States, although our total production is still far above the present Soviet total. Thus, the increase in industrial potential that might be expected from the development of the Russian coal industry is confirmed by the figures of steel and electric power production.

This expansion of Soviet coal output is the more remarkable in view of the vast destruction of Russian productive facilities that accompanied the German invasion, occupation, and retreat. Consider these appalling figures: 7 million Russian combatants killed; 38 million civilians made homeless; 31,000 factories, mines, and electric power installations, with their innumerable machine tools, motors, pumps, dies, fixtures, and shop drawings; 40,000 miles of railroad track, with thousands of cars and locomotives; 13,000 bridges; and 6 million buildings in 1700 cities, towns, and villages laid waste, destroyed or ruined by incendiary flames, artillery fire, aerial

* These include the *Economic Survey of Europe Since the War*, published by the United Nations, various trade and technical journals, such as the *U. S. News & World Report*, *Nation's Business*, British *Colliery Guardian*, *The Economist* of London, which is one of the finest, *The New Sketch* of India, and various others. The richest mine of information on internal Soviet affairs is *The Current Digest of the Soviet Press*, published each week at 1745 South State Street, Ann Arbor, by The Joint Committee on Slavic Studies, appointed by the American Council of Learned Societies and the Social Science Research Council.

bombs, demolition charges, flooding, and other ingenious means of destruction.

The impact on coal production is illustrated by the devastation of the Donets Basin coal field, called the Donbas. Before the war, that field mined 50 pct of Russia's coal. The Donbas seams are deep and pitching. Coal output was 94 million U. S. tons in 1940, nearly 90 pct of which came from 314 basic mines (800 to 1200 tons per day), operated by the Coal Ministry. Some 2000 smaller mines operated by various agencies accounted for the remaining output. The Coal Ministry also had 72 new mines with a further daily capacity of 110,000 tons nearly ready for operation. The Donbas was surrounded by a sizeable mining machinery industry represented by the Gorlovka, the Torets, the Komsomol, the Voroshilograd, and other plants that made coal cutters, mine hoists, fans, pumps, conveyors, pneumatic picks, jacks, etc., most of which went into the Donbas mines. The mines were equipped with thousands of such machines at the time of the German invasion.

The Nazis did a thorough job in the Donets Basin. In addition to the mining machinery plants, they destroyed the 314 basic mines and many of the smaller ones, wrecked 515 mine hoisting installations, and flooded or clogged mine shafts that totalled 1300 miles in vertical depth. In addition, the Donbas lost 64 pct of its housing.

Yet, Russian Officials claim that, after pumping out 620 million cu meters of water between 1942 and 1947, the Donbas coal production in 1949 was back to the prewar 94 million ton level from 182 restored old mines and 60 new mines, all completely modernized, with more mechanization than in 1940.

On the whole, the evidence indicates that Soviet recovery from the devastation of war has been far swifter than that of Western Europe. The Kremlin has offset Marshall Plan aid by drafting manpower, male and female, and working it hard and long, by looting Eastern German factories and laboratories of their machine tools and scientific instruments, and by kidnapping their engineers, plant managers, technicians, and scientists, by stripping the Japanese plants in Manchuria, and by requisitioning what they desired in skilled personnel and machinery from their satellites.

They understood that the only way to restore the ravages of war is to go to work—hard—and to keep at it. Further, they knew exactly what they wanted to build upon the wreckage of the last war, and why they wanted it. They have ruthlessly, mercilessly, and unwaveringly regimented and sacrificed the lives of their people to the attainment of that objective; viz., overwhelming economic power. And they understood that its cornerstone is modern, efficient coal mining.

The development of a creative mining machinery industry, therefore, was a basic necessity in the Soviet long range plan for their coal mining expansion. They had foreign machines of many kinds, cutters, loaders, conveyors, drills, and pneumatic picks, British, American, and German, in their mines. They had no regard for patent rights. They began by copying these foreign machines as best they could with their available metals, machine tools, and engineers. But they went on to educate more and better engineers, to improve their metallurgy, to develop a substantial mining machine industry, and vastly to enlarge machine tool manufacturing facilities. Furthermore, they had and have unimpeded access to all the patents, the technical and scientific publications, both private and governmental, with all their immeasurable wealth of information, that record the industrial and scientific progress of the Western World. Even before the war they were hard at work designing new and more productive coal mining machines. For years their main long range objective was mechanized continuous mining. Consequently, continuous mining machines, or *combines* as they call them, were high on their list of priorities.

In an article entitled "The Soviet Coal Mine Today and Tomorrow," A. M. Terpigorev, Member, Academy of Science, Stalin Prize Laureate, says:

"The Soviet coal mine has changed beyond recognition. . . . Practically all the arduous operations had been mechanized already before the war. And, in recent years, Soviet designers, working in cooperation with engineers and miners, have created more than 130 new types of machines.

"Among the new machines which have appeared in Soviet coal mines since the war are coal combines. These splendid machines, which the USSR was the first to produce, simultaneously perform the three principal operations in the mining of coal; cutting (they cut into the coal seam, leaving a slit in it), breaking down (they bring down the coal above the slit, separating it from the solid mass) and piling (they dump the broken-down coal on the conveyor).

"Three coal combines stand out among the different types put out and they are in use more widely than any of the others. These are the 'Donbas,' 'UKT-1' and 'KKP-1.' Their designers received Stalin Prizes.

"These combines are intended for use in working different seams.

"The Soviet coal-mining industry occupies first place in the world for the degree of mechanization of labour."

Apropos of this last assertion, it is difficult to know whether by *mechanization*, Russian writers mean just what we mean by that term. For example, in some instances, the introduction of pneumatic picks is described in Soviet statements as "mechanization." We would not so classify such a change. Further, "who wants to impress whom about what" appears to make quite a difference in what a communist writer says about Soviet coal mine mechanization. Thus, evidence cited later indicates that Mr. Terpigorev may be stretching the facts somewhat for the purpose of impressing the satellites and the rest of the world with the alleged miracles of Soviet accomplishment.

Note that three different continuous miners, or combines are mentioned by Terpigorev as the most widely used, but many others have been built and tried in Soviet mines, as indicated by articles and pronouncements in Soviet newspapers and journals, with varying degrees of success. Indeed, the article in question is illustrated by an artist's sketch of a fourth machine, the UKSH-1 combine, for continuously mining coal in pitching seams.

A description of this or a similar machine by D. D. Evans* states that "it was 3 tons in weight and had picks 6 to 7 in. in length, fixed into a revolving frame, which slid in sleeves up and down the length of the cutter, shearing the coal in the process, which was then left to fall down the face into a bunker on the lower road." The machine was operating on a 175-yd face on a 45° pitch. "It was estimated that a

* Mechanization, Vol. XVL, No. 8, Aug. 1952.

team of four men with this machine could produce 250 tons of coal per day under such conditions, provided the length of face was available." In other words, provided an undisclosed number of additional men on that long wall face could do the necessary rock ripping and pack work, move and set the necessary jacks, advance and load out the stalls to permit full shift operation of the combine.

Mr. Evans reports that in another mine they "saw a coal cutter with a circumferential jib with picks fitted to two revolving frames with a worm-like arrangement, so as to work the coal towards the edge of the previous cut, after which it slid down the coal face to the loading point." This may have been a "Donbas Combine."

Another Soviet writer states that the Donbas combine on the average produces in excess of 200 tons per shift from a 12-man crew, or an average of 10 to 12 tons more per man shift than working with an ordinary cutter, and states further that it cuts a strip of coal 1.5 meters deep.

But when we listen to remarks from some of the miners themselves, we discover that new Soviet mining machines, as here and elsewhere, are full of "bugs," and in their introduction Russian miners stumble over the same troubles that plague us here, dust, gas, bad roof, rock bands and pyrite inclusions, timbering, and transportation bottlenecks. Furthermore, there is criticism of Soviet officials for ineffective design, for unhappy delays in the development and introduction of suitable machines, and for just about all the shortcomings that American coal operators ascribe to American mining machinery manufacturers.

Accurate comparisons can not be made between the Soviet long wall continuous mining machines and those in use in Great Britain for lack of detailed information. However, it does seem that the Donbas continuous miner and probably most of the other Soviet machines are built around the principle of cutting enough coal out of the seam so that the weight on the face, or components of the machine, will bring down the rest of the cut and either gravity or the machine itself puts this broken coal onto the face conveyor. This is the general principle used in the British Meco-Moore machine, perfected during the war.

It seems probable that the U.S.S.R. has not thus far developed long wall machines and methods superior to those of the British, Dutch, French, Belgians, and Germans, but it does seem likely that the Russians are introducing their machines into their mines and perhaps making improvements at a faster rate than the Western European nations.

About 60 pct of subjugated Poland's 93 million annual tons of bituminous coal comes from room and pillar mines, equipped with heavy track, powerful electric haulage locomotives, and capacious steel mine cars. Polish and Czechoslovakian mines are using Russian-made copies of the latest types of American cutting machines, loaders, and shuttle cars. In fact, Polish and Czechoslovakian postage stamps bear pictures of Joy type crawler-mounted loading machines and rubber tire, wheel-mounted universal cutting machines at work in their coal mines as evidence of communist technological progress in underground mechanization. The output per man shift in Poland is the greatest in Europe and approaches many American mechanized mines.

In the higher levels of Soviet administration there is vision, determination and planning for new machines and advanced underground techniques that

COAL PRODUCTION

(In Millions of Net U.S. Tons)

Country	1928	1938	1940	1947	1948	1949	1950	1951	1952	(Planned) 1955
Western Europe (a)										
Belgium-Luxembourg		33		27	29	31	30	33	34	
France		51		50	48	56	60	58	61	
Saar		16		11	14	16	17	18	18	
Western Germany		153		80	97	116	129	133	136	
Netherlands		15		11	12	13	13	14	14	
Spain		6		12	11	12	12	12	14	
United Kingdom	261	254		221	234	241	242	250	253	
Total		528		412	445	485	503	518	530	
United States	576	374		688	657	484	560	576	502	
Canada		14		16	18	19	19	19	18	
Total		388		704	675	503	579	595	520	
Communist countries										
Czechoslovakia		18†		18*	20(a)	19(a)	20(a)	20(a)	22(a)	
Eastern Germany (a)		4		3	3	3	3	3	4	
Hungary		1(a)		1*	1*	2*	2*	2*	2*	
Poland (a)		76		65	77	82	86	90	93	
Russia										
Coal—lignite	43(b)	146*	183*	173*	226*	260*	29[illegible]*	310*	332*	416(c)
Peat		(29)	(34)				(51)			(65)
Total		245		260	327	366	402	425	453	

† United Nations, Statistical Yearbook, 1949-50.
* U. S. Department of Interior, Bureau of Mines, Minerals Yearbook 1945, 1951 & 1952.
(a) From United Nations *Economic Survey of Europe Since the War*, Geneva, February, 1953, Appendix A, Table VI, p. 244.
(b) Herbert Harris, *Nation's Business*, September, 1953, Vol. 41, No. 9, p. 75.
(c) *New York Times*, August 23, 1952.
Quarterly Statistics Iron & Steel Industry in the U. S. S. R., Publisher: Statistical Office, West German Republic, Dusseldorf, May, 1953, gives following figures for Russian output (in millions U. S. net tons): 1947—223; 1948—249; 1949—273; 1955 (planned)—450.

intrigue our interest and command our attention. U.S.S.R. First Deputy Minister of the Coal Industry A. Kuzmich states that the successful introduction of new equipment and the improved organization of production has made it possible to increase coal output 27.7 pct in the last 3 years and raise the productivity of labor by 23.6 pct. Then he lists vitally urgent problems that remain to be solved in Soviet coal mine mechanization:

1. "Converting advancing to retreating methods of working sectors and mine fields." This arouses speculation as to whether Kuzmich is referring to changing over from long wall mining to room and pillar methods, in consequence of his observation of the Polish productivity. If so, it is especially interesting at this time, when some of our progressive American coal mining companies are trying out long wall mining in this country and when the advantages of one method over the other provide an animated subject of international discussion by European and American mining engineers.

2. "Change over old methods of mine management, layout and operation of the new methods required for efficient mechanized mining."

3. "Develop and introduce continuous tunneling machines." Here Kuzmich says:

". . . The new SMB-1 tunneling combines introduced in the Donets Basin mines mechanize all work connected with tunneling except bracing and make it possible to raise tunneling tempos to two to two and one-half times those when loading machines are used. Work is being done to develop new types of tunneling combines for heavy rock strata."

4. "Mechanization of propping:" Says Kuzmich on this subject:

"Persistent work by Soviet designers and inventors has recently made the solution of this problem quite practical. Tests have already been made of two types of mechanized propping for Donets Basin and Moscow Basin mines. Even with most favorable test results, however, these types of propping will be suitable only under limited mining conditions. The necessity of extensively introducing mechanized pit propping in stopes, as stated in the 19th Party Congress directives, demands that we miners radically increase work to develop mechanized propping for various mining conditions."

5. "Remote control of automatic operation of machinery in mines."

On this subject, listen to this revelation:

"During the fourth Five-Year Plan coal industry workers made the first steps toward the automatic operation of machinery in mines—certain types of equipment for automatic operation were developed, the production base for their mass production was established and certain designs were put into use. Now thousands of combines, cutting machines, scraper conveyors, pushers, and hoists are operated by remote control in mines and much pumping equipment has been made automatic.

"Under the present Five-Year Plan the transition must be made to remote control operation, with automatic protection, of combines, cutting and loading machines, and automatic pumping equipment must be more widely used. The use of automatic signals, centralized operation and blocking in underground transportation of coal mines will be expanded."

6. "Underground hydraulic coal extraction:" Here is another revealing quotation:

"The use of hydraulic engineering methods in coal mines is also in prospect. Technical means for underground hydraulic coal extraction have already been developed. Industrial exploitation of a complex for hydraulic coal extraction began in a Kuznetsk Basin mine at the end of 1952."

It is impossible to say how much is fact and how much is guileful deception in such Soviet statements. Careful screening and consideration of all the known facts and confirming evidence, however, lead to these conclusions:

1. A more rapid expansion of coal production is going on in the U.S.S.R. than in any other important coal producing country.

2. Mechanization of mining is probably proceeding at a faster pace there than anywhere else in Europe.

3. The Soviet objective is automatic, remotely controlled, continuous coal mining.

4. This mechanization is based on a well directed, effectively organized, and rapidly expanding creative mining machinery industry that, at least in volume of product, probably has no counterpart in Western Europe.

The expansion of Soviet coal production and the drive for advanced mechanization holds a grave significance for us and for all free countries. To understand its portent, it is necessary to digress a moment to clarify a point of view and to present a philosophy of life quite alien to us.

Our concept of Western Europe is that of an area that has achieved great industrial and cultural attainment over centuries of peace interrupted now and then by periods of warfare. That picture is upside down. The truth is that Western Europe has been continuously at war for 20 centuries, interrupted by interludes of peace. Study your history and reflect upon the record. In the 335 years from 1618 to 1953, the nations of Western Europe have spent almost one-half of those years in warfare. For centuries, war has been the chief business of that continent. It has been the ruling consideration in statecraft, and in domestic and international policies. Nations fought a war and reached a peace. They cleaned up the wreckage, rebuilt their shattered towns and homes, recast their lives, and then their governments have gotten them ready to fight the next war.

Never have the people of those lands wanted war. Always it has been brought upon them by their rulers, "the kingliest and worst of all kingly tyrannies," as Lincoln described it.

The actions of the Soviet rulers lead to the conviction that the buildup of Russian industrial power is not primarily for the purpose of improving the the standard of living of their people, but to provide the basis for conquest. They have read and understood the lessons of the last two wars. Said Von Hindenburg, "it was the American manufacturers who defeated us. They understood war." He did not mean that they understood military strategy and battle tactics. He meant that they understood how to turn out guns, shells, tanks, planes, and ships in overwhelming, irresistible numbers.

Stalin said, "Production wins wars." So the U. S. S. R. will have production, will build up industrial power to overwhelm all opposition, at whatever bitter sacrifices imposed upon the subject peoples.

That is the stark significance for us of the rapid increase of Soviet coal production and of the Soviet drive toward the most effective mechanization of their mines that they can devise.

Copper Soil Anomalies in the Boundary District Of British Columbia

by W. H. White and T. M. Allen

THE Greenwood-Grand Forks area of southern central British Columbia, known as the Boundary District, has a long history of mining exploration and production. At the turn of the century this was the premier copper mining camp in the British Empire, its total production amounting to some 20 million tons. Most of this ore came from the great Granby mines at Phoenix, but the Motherlode mine at Deadwood camp, 6 miles to the west, and several mines in Summit camp, 5 miles north of Phoenix, made important contributions. The large deposits were exhausted in 1918 and the district since has seen only desultory exploration and salvage operations.

The orebodies are mineralized skarn zones in limestone members of a thick series of Upper Paleozoic sedimentary and volcanic strata. Chalcopyrite is the primary ore-mineral. Copper carbonates and silicates occur sparingly in outcrops, but the oxidized zone generally is very shallow. Much of the surface is mantled by glacial drift which in most places ranges in thickness from 2 to 15 ft. In some of the hanging valleys, however, the glacial drift may be as much as 100 ft thick and may assume drumlin-like forms.

In 1951 an ambitious program aimed at the discovery of new orebodies and important extensions of abandoned deposits was launched by Attwood Copper Mines, Ltd. In this district so thoroughly searched by an earlier generation of prospectors, any orebody which had remained undiscovered must have little or no surface indication. Consequently, in addition to the basic detailed geological work, the program of exploration included magnetometer and self-potential surveys. *Geological bets* and geophysical anomalies were tested further, prior to diamond drilling, by a study of copper distribution in tree twigs and/or in the soil. The soil sampling and analytical methods used and some of the results seem of sufficient importance to warrant this paper.

The authors had done some plant sampling in this and other districts, using the dithizone neutral-color-end-point method (Warren and Delavault, 1948, 1949; White, 1950),[1-3] but they were unfamiliar with its soil application. Finally, after much experimenting in the field, they adopted the methods described here. These methods are not entirely original or defensible on theoretical grounds, but under field conditions of rapid sampling and analysis the results are reliable enough to be of use. Fig. 1, which shows the results of duplicate analyses of duplicate soil samples taken at 50-ft intervals across an anomalous zone, indicates the relative dependability both of the sampling and analytical methods.

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Sampling and Analytical Equipment

A 2-ft piece of 1-in. solid drill steel, one end sharpened to a broad, conical point. The steel is marked at 1 ft from the point.

A 2-ft piece of ½-in. black iron pipe, one end filed to a bevelled cutting edge. The pipe is marked at 1 ft 3 in. from the cutting end.

A 3-lb hammer.

A plastic or rubberized sheet about 18 in. square.

Moisture-proof assay pulp envelopes.

A 10-mesh seive made from window screen with the paint burnt off.

A small assay spatula.

A pan balance sensitive to 10 mg.

Two ignition trays about 4 in. square, made of sheet iron turned up along the edges.

A Coleman two-burner gasoline stove.

An asbestos board about 5x8 in., used as a hot plate on the gasoline stove.

A circular aluminum rack to hold 8 test tubes while refluxing (design of Almond and Morris).

Pyrex Glassware

Large refluxing test tubes, 25x200 mm, marked at 40 ml volume.

Breakers, 20 ml.

Pipettes, 1, 5, and 10-ml capacity.

Graduate, 50 ml.

Shaking cylinders, 100 ml, glass stoppers.

Burette, 25 or 50-ml capacity, with holder.

Chemical Supplies

1 N sulphuric acid.

Hydroxylamine hydrochloride, solid crystals.

Fisher Alkacid test paper.

Copper standard solution.

Dithizone standard solution 60 mg per liter.

Water reasonably free of metals.

Soil Sampling Method: The problem of how to take a soil sample is extremely crucial. The method outlined below, adopted after a number of tests, has the advantages of uniform pattern, uniform depth, and uniform size of sample.

The area to be tested was marked off by chain and compass lines 100 ft apart, normal to the strike of possible ore deposits. Numbered stakes were set at 50-ft intervals along these lines and a soil sample was taken at each stake in the following manner.

The drill steel was driven into the ground normal to the slope of the surface to the marked depth of 1 ft, moved slightly from side to side, then carefully withdrawn. The iron pipe was inserted to the bottom of this hole, tapped down to the marked depth of 1 ft 3 in. and withdrawn; the 3-in. soil plug in the

The Transactions papers appearing in Mining Engineering during 1954 will subsequently appear in AIME Transactions Vol. 199 and may be permanently referenced to that volume.

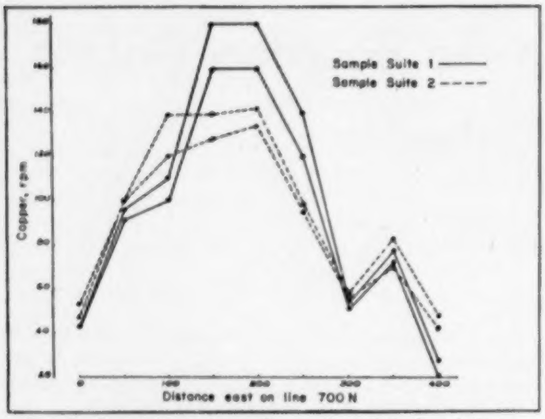

Fig. 1—Comparison of sampling and analytical variations. The dots represent analyzed samples.

end of the pipe was knocked out on the plastic sheet. Five such samples taken at each corner and at the center of a 6-ft square, combined on the sheet and transferred to a pulp envelope, made up the sample for the station. Sample weights averaged 50 g.

Preparation of Sample: At a field laboratory housed in an old shack each sample was seived and the oversize discarded. At the outset samples were pulverized, but this proved laborious and unnecessary. The screened sample was spread on a sheet iron tray, placed on the open burner of the gasoline stove, and ignited at red heat. The purpose of ignition was to break down soil aggregates and colloids and to ash organic material. The cooled sample was mixed on a plastic sheet and coned and flattened, and the 2-g sample for analysis was weighed out. This was transferred to a large test tube for digestion.

Digestion: After the addition of 30 ml of 1 N sulphuric acid, the tube containing the sample was placed in a rack on the stove and refluxed for *exactly* 30 min. The burner was so adjusted that moderate bumping agitated the contents of the tube. At the end of this period water was added to bring the volume to 40 ml, refluxing was continued for *exactly* 5 min, and the tube was set aside for half an hour to cool and settle. The procedure up to this point is described elsewhere,[4] but now a departure is made.

The next step was to transfer a 10-ml aliquot of the supernatant liquid to a 20-ml beaker to which has been added about 200 mg of hydroxylamine hydrochloride. The beaker was heated gently on an asbestos pad until the liquid had evaporated almost to dryness, that is, the center bottom of the beaker became dry. Then the beaker was removed and the contents diluted with 20 ml of water. This solution would have a pH of about 3, optimum for copper analysis using dithizone.

The procedure described in the last paragraph was found essential if all oxidizing influences were to be removed from solution, as they must be for accurate copper analyses. With this method failures due to oxidation of dithizone were less than 1 pct. On the other hand, using the method of Almond and Morris, wherein Thymol Blue indicator is added to the sulphuric solution which then is neutralized to pH.3, the authors experienced a high percentage of failures due to oxidization. Furthermore, the color of the indicator interferes with the end-point in the subsequent titration.

Titration: A suitable aliquot, usually either 1 or 5 ml, of the aqueous solution was pipetted into a shaking cylinder for titration by the neutral-color-end-point method, which is described elsewhere.[1,3] This method is considered superior to the mixed-color methods widely used in the United States. First, partial oxidation of the dithizone, the chief danger in copper analysis, becomes immediately apparent, and second, all operators, even those slightly color-blind, get almost identical end-points.

The authors keep their supply of dithizone in solid form in folded paper packets, each containing exactly 15 mg of the reagent. Fresh solution is made up merely by dissolving the contents of a packet in a 250-ml reagent bottle of carbon tetrachloride. Each new bottle of dithizone solution is standardized, since for some unknown reason the copper equivalent may vary from one batch to the next by as much as 10 pct. To standardize, a blank to which has been added a measured quantity of standard solution of known copper content is put through the entire sequence along with the regular samples.

A three-man crew was used for the Attwood soil sampling program, two taking samples and one making the analyses. Highly-trained operators are not necessary. For example, after a short period of instruction and observation, a high-school boy became one of the best analysts. The rate averaged about 50 samples per day, a coverage at the spacings used of about 5 acres per day. Depending on rates of pay, the cost of such a program would be between $6 and $8 per acre. On a larger project costs could be reduced by greater duplication of equipment.

Examples of Copper Soil Anomalies

Soil anomalies related to known or partly-known orebodies in the Deadwood, Summit, and Phoenix camps will serve to show the kind of results which can be expected. These examples may illustrate as well some of the main characteristics of copper soil anomalies.

Fig. 2—Example A, Deadwood camp, showing distribution of ore and of copper soil anomaly. The heavy dashed lines are copper soil contours.

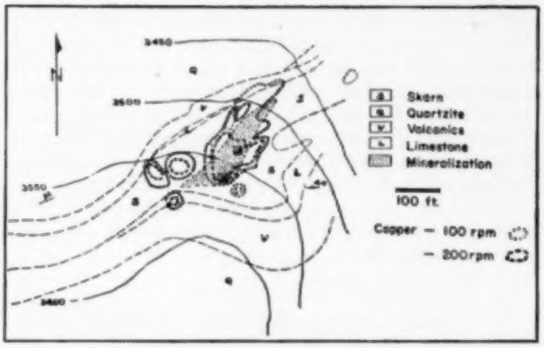

Fig. 3—Example C, Summit camp, showing distribution of ore and of copper soil anomalies. Note that the copper values are much lower here than in Fig. 2.

Example A, Deadwood Camp: Fig. 2 shows the main features of this property. The low hill flanked by broad, flat-bottomed valleys is skarn containing calcite, epidote, garnet, actinolite, and hematite. Occasional flakes of malachite in outcrops and old pits indicate that the skarn in general is very slightly mineralized. Glacial drift ranges in thickness from 2 to 7 ft on the crest of the hill, becoming thicker on the flanks.

The projection of an orebody of commercial grade, as it is known at present from subsequent diamond drilling, is shown on Fig. 2. Copper mineralization, though not necessarily of ore grade, continues both North and South at least 200 ft beyond the limits shown on the map. The ore consists of the same skarn minerals found at the surface and in addition disseminated grains and small veinlets of chalcopyrite. This orebody is blind; nothing of commercial grade is known on the surface. Its closest approach to the surface is 75 ft and much of the orebody is more than 200 ft from the surface.

The distribution of copper in the soil is shown by contours on Fig. 2. Values in excess of 100 ppm are considered anomalous, and the local areas of higher copper content within the 100-ppm contour appear to have little significance. The anomaly is positioned roughly over the orebody and has a similar trend, but it has spread laterally and migrated a short distance downhill.

A magnetometer survey was made of this area. A magnetic anomaly was detected which was low and broad, roughly circular in plan and about 400 ft in diam. The orebody is more closely related in size, shape, and trend to the soil anomaly than it is to the magnetic anomaly.

The question arises as to whether the existence of this soil anomaly over an orebody which is *blind* is rational or fortuitous. It may be that the soil anomaly indicates merely the disperse copper mineralization in the skarn at the surface, which, fortunately in this instance, is related in turn to commercial ore at depth.

Example B, Deadwood Camp: A property not far from Example A will serve to show how negative results from a soil survey can be of value. The property was completely mantled by glacial drift and heavily timbered. Magnetometer work revealed several anomalies almost identical in shape and intensity to that of Example A. When the property was mapped it was found that some, but not all, of the magnetic anomalies occurred on drumlin-like hills, and doubt was expressed as to the significance of the anomalies. Consequently a soil survey was made prior to further development work. This revealed isolated high values—one sample returned over 4000 ppm copper—but no pattern of anomalous values which could be contoured rationally. A little digging proved that the magnetic charcteristics were a surface phenomenon. The magnetism was caused by magnetite sand and by large float boulders of magnetite containing some chalcopyrite, and anomalies appeared over drumlins and buried channels where the glacial drift was unusually thick.

Example C, Summit Camp: A small, relatively high-grade copper orebody in the Summit camp, which was fairly well exposed, was used to test the soil sampling and analytical methods. A lens of limestone in quartzite and greenstone has been altered in part to garnet-rich skarn, and the orebody is a well-defined mineralized zone in the skarn. The soil is rocky glacial and local drift, thin and patchy, containing much humus.

Fig. 3 shows the geology, surface outcrop of the orebody, and the copper soil anomalies. In this instance soil samples were taken at 25-ft intervals. The main anomaly is about the same size and shape as the orebody and is displaced about 75 ft downhill. The cause of the several smaller anomalies is not known.

This orebody outcrops and is of higher grade than that of Example A, yet the copper values within the anomaly are much lower; 200 ppm is the highest contour. Hence there appears to be no rational relation between copper values in the soil and those in an underlying mineralized zone.

Example D, Phoenix Camp: Fig. 4 shows an area in Phoenix camp of much interest because it adjoins a large near-surface orebody which has a fault termination. Several big gloryholes and waste dumps are only about 300 ft uphill. The bedrock in this area is completely obscured by a thick mantle of silty glacial drift, and it was hoped that a soil survey would provide some targets for the diamond

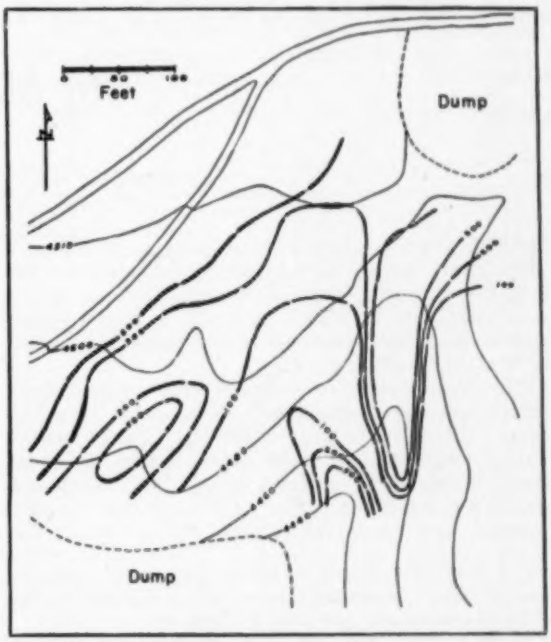

Fig. 4—Example D, Phoenix camp, showing the dispersion of copper in the soil in relation to topography. The heavy dashed lines are copper soil contours.

drill. The copper contours on Fig. 4 show that in this instance the soil survey completely failed its purpose. The copper content of the soil is anomalous throughout the area, but the distribution of copper in the soil is related solely to the topography. The greatest concentrations of copper lie along a gully which drains the large mined areas and dumps farther uphill. Evidently under such conditions of deep drift, moderate slope, and good drainage, copper in the soil can migrate differentially for distances of at least several hundred feet from its source.

Conclusions

1—Soil sampling and analysis for copper is a valid technique which properly can be included in a program of exploration for copper ore deposits.

2—Probably its greatest use will be for secondary testing of *geological bets* or anomalies obtained by geophysical methods. The cost, although not prohibitive, still is too high to permit wide use of the technique for primary prospecting.

3—Isolated spot testing is useless. Copper soil anomalies are valid only when they appear as rational contours on the map of an area that has been sampled systematically.

4—These anomalies must be interpreted with due regard to the geomorphic history of the area. They may correspond closely to the source of the copper, or, alternatively, they may have spread and migrated considerable distances. Probably in the latter instance a *tail* could be detected leading back to the source of the copper.

5—In the Boundary District of British Columbia the normal copper content of the soil is less than 100 ppm, averaging about 27 ppm. Copper values over 100 ppm can be considered anomalous. Probably in another district having different types of rocks and soils and a different climate other values would represent normal and anomalous relations.

6—A copper soil anomaly does indicate the presence of unusual amounts of copper in the underlying or contiguous bedrock, but it does not indicate, necessarily, the presence of a commercial orebody. It follows that a strong anomaly is no better indication of an orebody than a weak anomaly.

Acknowledgments

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Gravity Surveys for Residual Barite Deposits In Missouri

by Robert P. Uhley and LeRoy Scharon

TEST gravity surveys were made in the Washington County barite district of Missouri on property owned by the Baroid Sales Division of the National Lead Co. This property is located just northeast of Richwoods in the northeastern corner of Washington County, Fig. 1.

The area to which the surveys were confined comprised approximately 5000 acres, of which some 525 acres were surveyed gravitationally. Gravity observations were made at 2600 points within the area, observations being confined to relatively clear and gently sloping ground. Part of the area was heavily wooded, and the terrain too rugged for either the occurrence of a commercial barite deposit or a feasible gravity survey. The relief along the central drainage, Ditch Creek, was about 140 ft, the maximum difference in elevation being 400 ft in a distance of 3½ miles.

The purpose of the test gravity survey was to determine whether the gravity method of geophysical prospecting might be applied in the exploration for barite deposits in the Washington County barite district, since a satisfactory systematic procedure had not been devised to explore and ultimately determine barite ore reserves with desired accuracy.

No previous geophysical work with respect to barite is known to have been done in this area.

Stratigraphy: The formations over which the barite deposits occur[1] are Paleozoic in age, representing rocks involving sandstones and dolomites unconformably underlain by pre-Cambrain granites and rhyolite porphyries. The areas covered by the granite survey were directly underlain by almost

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flat-lying Potosi-Eminence and Gasconade dolomites which are Cambrian and Ordovician in age.

The Potosi formation is characterized by irregular masses and discontinuous beds of honeycombed drusy quartz. The weathering of the Potosi and possibly younger overlying formations has produced a residual mantle of dark red clay containing in its lower portion the residual barite which furnishes the larger production of ore.

The surface of the Potosi bedrock under the gravity areas was assumed to be somewhat flat-lying. This assumption was substantially valid but the gravity anomaly surface had a tendency to parallel the irregularities of the bedrock surface.

Ore Deposits: The residual barite occurs in a deep red plastic clay anywhere from the surface down to a depth of 20 ft. The lower portion of the deposit generally consists of red plastic clay, drusy quartz, and large blocks of barite. These blocks were sought by hand-miners who operated in the area prior to mechanization. Above this is a zone of gravel barite, disintegrated drusy quartz, and chert. Several feet of tillable leached and barren soil may occur at the surface.

The gravel barite, passed over by the hand-miners, makes the best feed for the log washers now employed to recover the barite but may be absent in some hand-mined areas.

Drusy quartz, chert, hydrous iron oxide, and a trace of galena generally are intimately associated with the ore. Some sphalerite, galena, chalcopyrite, pyrite, and barite occur along fractures in the bedrock. Origin of barite in this area is unknown.

Theoretical Considerations: The gravitational principle of prospecting is dependent on a density contrast mass of sufficient size to be measurable. In the area under consideration the basic densities involved were those of bedrock, soil, quartz, and barite. These densities were ascertained by comparison and averaging of chemical balance and weight-volume measurements with the densities of the materials in question as listed in the literature.[2] The densities were as follows: dolomite 2.88, soil 1.7, quartz and chert 2.6, and barite 4.5. The density contrasts with the soil were barite 2.7, quartz 0.9, and dolomite 1.2. Although barite had the highest density contrast, concentrations of quartz or dolomite in the residuum could produce a positive gravity anomaly. However, bedrock was assumed to be relatively flat-lying and quartz and chert were assumed to be uniformly distributed in the soil. These assumptions were invalid where *flint-bars* and bedrock pinnacles occurred.

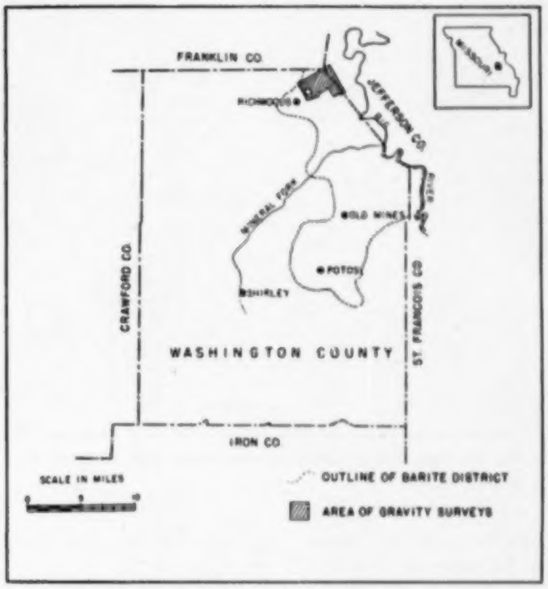

Fig. 1—Index map showing location of gravity surveys, Washington County, Mo.

Fig. 2 is a theoretical gravity anomaly[3] over a hypothetical orebody, rectangular in plan and of infinite length, having a density contrast of 0.5 and 1.0 g per cu cm. The density contrast of 0.5, which most nearly fits the case, represents a mixture of soil and barite containing about 40 pct barite by weight and produces a maximum anomaly of about 0.06 milligal. Superimposed on the theoretical

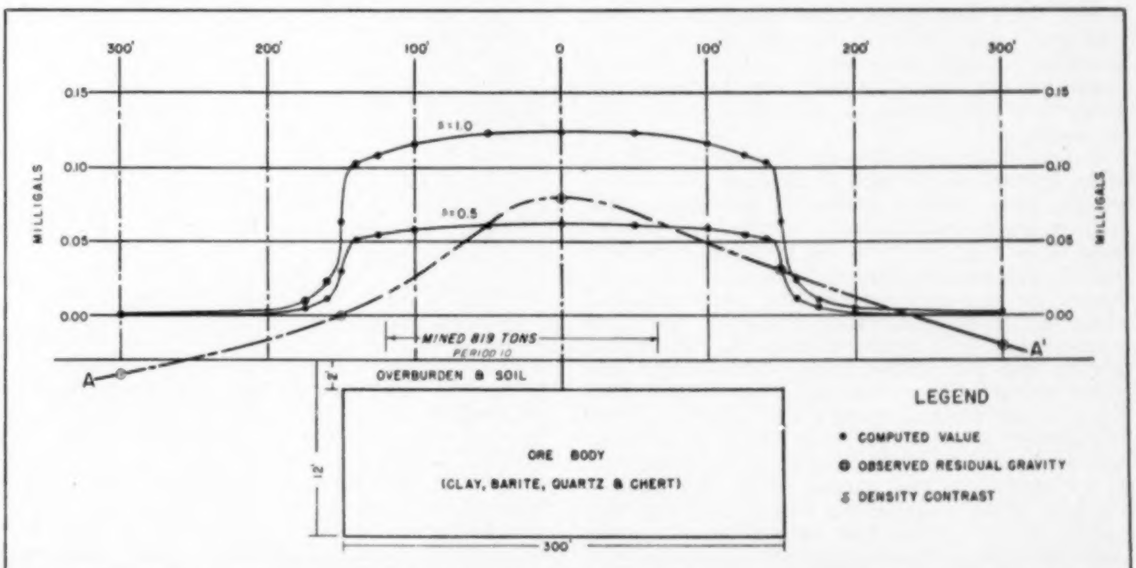

Fig. 2—Theoretical and observed gravity anomalies over a barite orebody.

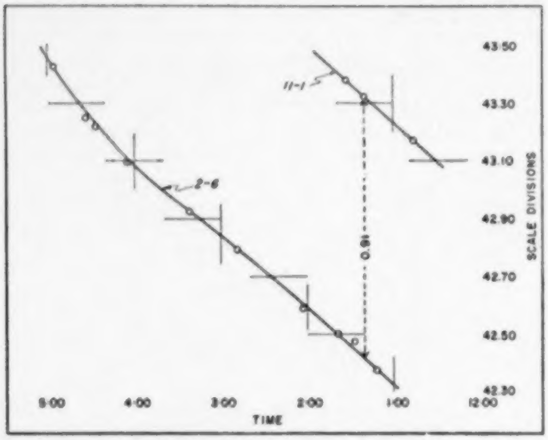

Fig. 3—Typical drift curves showing linear drift of Worden gravity meter.

profile is a measured residual gravity anomaly, A-A′, over an orebody.

A series of 20 gravity observations on two stations with the Worden gravimeter[3,4] at the Houston Technical Laboratories had a probable error of 0.02 milligal, or about 33 pct of the anticipated anomaly. Repeated readings on 19 different stations in the field had an average difference of a little less than 0.02 milligal.

Grid systems varying from 50 to 100 ft between stations were laid out with range poles and chain in small areas and with the aid of a transit in larger areas. The maximum error in station location was estimated to be 15 ft, or a maximum of 0.015 milligal. Elevations were determined to 0.1 ft or better, which was equivalent to about 0.006 milligal of Bouguer anomaly. The average density for the Bouguer correction was determined to be 2.6 by the density profile method.[5] The surveys were confined to relatively open and flat ground.

Base station observations were made at approximately hourly intervals to obtain a detailed drift correction.

Fig. 3 is a drift curve which shows the constant and linear drift of the instrument. Shocks to the gravimeter caused some erratic drift, but this was somewhat eliminated by returning the instrument to the base station after the occurrence of any kind of shock.

Results: Combined free-air Bouguer corrections were applied to the data to produce the relative gravity data. Terrain corrections were not applied in as much as the maximum terrain correction in most areas was less than the probable error of a gravity observation. The regional gravity was removed by averaging symmetrical points within a circle of 150-ft radius and subtracting from the station value. This method of removing the regional gravity was not mathematically unique but produced a reasonable residual gravity map. The relative and residual gravity data were compiled in the form of isogal maps from which an attempt was made to estimate the approximate tonnage of barite ore within the residual highs. All positive residual gravity anomalies were analyzed and anomalies of 0.03 milligal or greater, extending over four stations, were considered significant.

The only grid on which gravity measurements were made and tonnages computed and then checked by mining was the Horine tract located in the extreme southwestern corner of the survey area. On this grid 269 gravity stations were occupied.

The relative gravity map of this area, Fig. 4, shows a strong gravity gradient toward the northeast. The gravitational anomaly surface is a warped plane with a rather prominent positive nose in the central part and a negative valley in the northern part. The positive nose was partially attributed to barite mineralization.

Fig. 5 is the residual gravity map of the same area. The areas considered significant on this map were: 1—the central area centered on an 0.08 milligal anomaly, 2—the narrow positive anomalies in the southeast corner, and 3—the northwest corner. The dashed line represents the outline of the mined area for which tonnages were recorded and compared to the tonnages computed from the residual gravity anomalies. Fig. 2 showed section A-A′.

Tonnages for the mined area were computed by determination of volume between the zero gravity plane and the positive residual gravity surface.[6] The mass in 2000-lb tons was equated to 2.44 times the volume in milligal feet squared. A factor was not used for the density contrast because it was assumed equivalent to the mining recovery factor.

Table I. Estimated Tonnage vs Mined Tonnage, Horine Tract

Period	Tonnage Estimated	Tonnage Mined	Error, Tons	Error, Pct
1	620	842	− 222	− 26.4
2	860	666	194	29.1
3	270	475	− 205	− 43.2
4	20	400	− 380	− 95.0
5	860	537	323	60.2
6	840	609	231	26.4
7	310	558	− 248	− 44.4
8	280	395	− 115	− 34.4
9*	1600	531	+ 1069	201.0
10*	2000	819	1181	145.0
Total	7660	5832	1828	31.5

* Shallow bed rock revealed by mining.
Error in total estimated tonnage, 31.5 pct.
Error in total, excluding periods 9 and 10, 9.5 pct.

Ten mining periods were surveyed and the tonnages recorded for each period. Table I lists the tons of

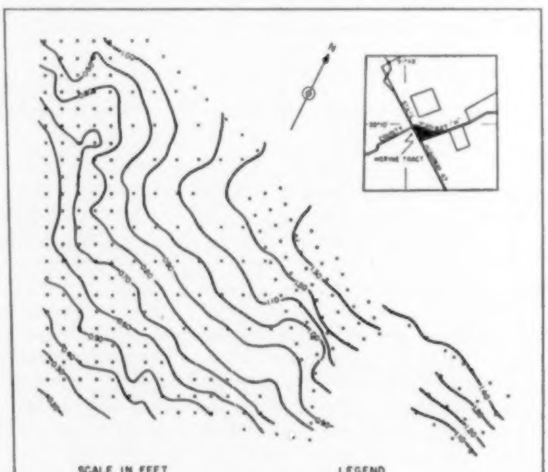

Fig. 4—Relative gravity map of Horine tract, Washington County, Mo.

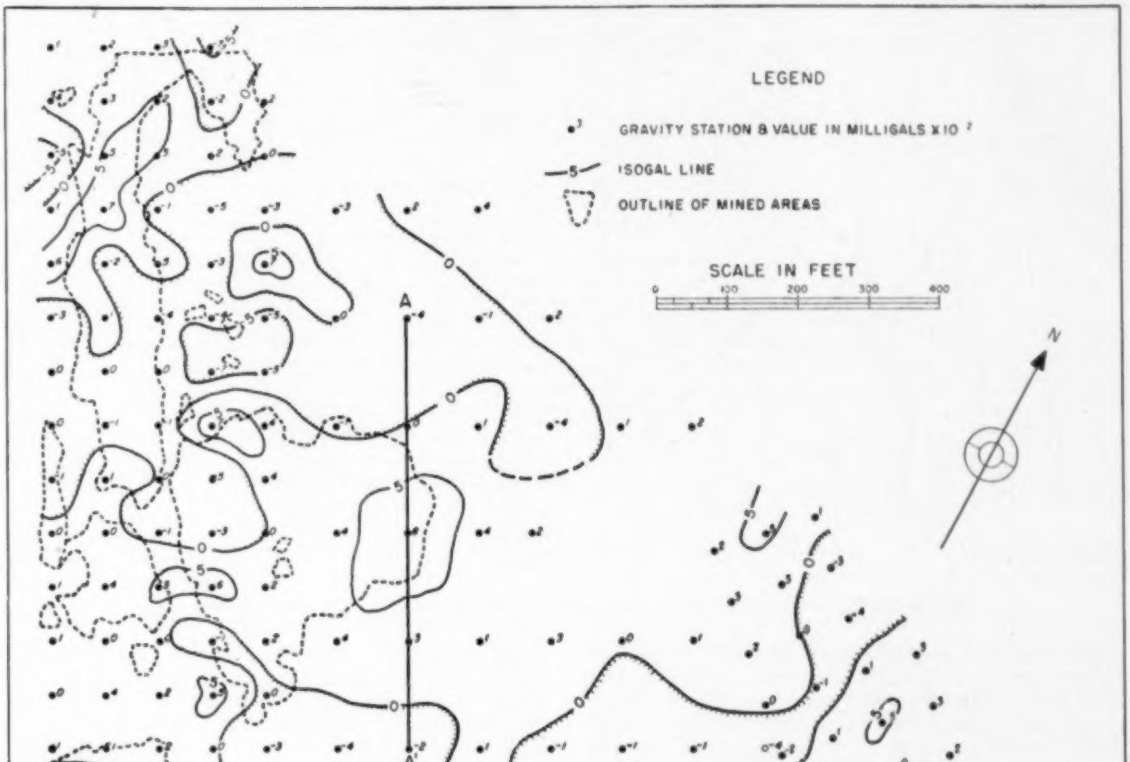

Fig. 5—Residual gravity map of Horine tract showing mined-out areas, Washington County, Mo.

barite recovered for each mining period vs the tons computed from the gravitational data. This gave an error in the total estimated tons of 31.5 pct. It should be noted that the last two periods were influenced by shallow bedrock; if they are excluded, error in total estimated tons is only 9.5 pct.

For contrast purposes typical relative and residual isogal maps prepared from one of the featureless areas are shown in Fig. 6. The one station low noticeable on the 1.9 milligal contour line was attributed to error. The small highs and lows on the residual map were considered insignificant. Test pits in the area were not recommended; however, they were made to test geophysical conclusions. The pitting did not reveal commercial mineralization but did aid in evaluation of gravity data in other areas.

Numerous test pits were dug to check gravitational results in other areas. The relative gravity maps of these areas were almost featureless, indicating the absence of large density contrast masses. Fig. 7 is a bar graph illustrating that in areas of

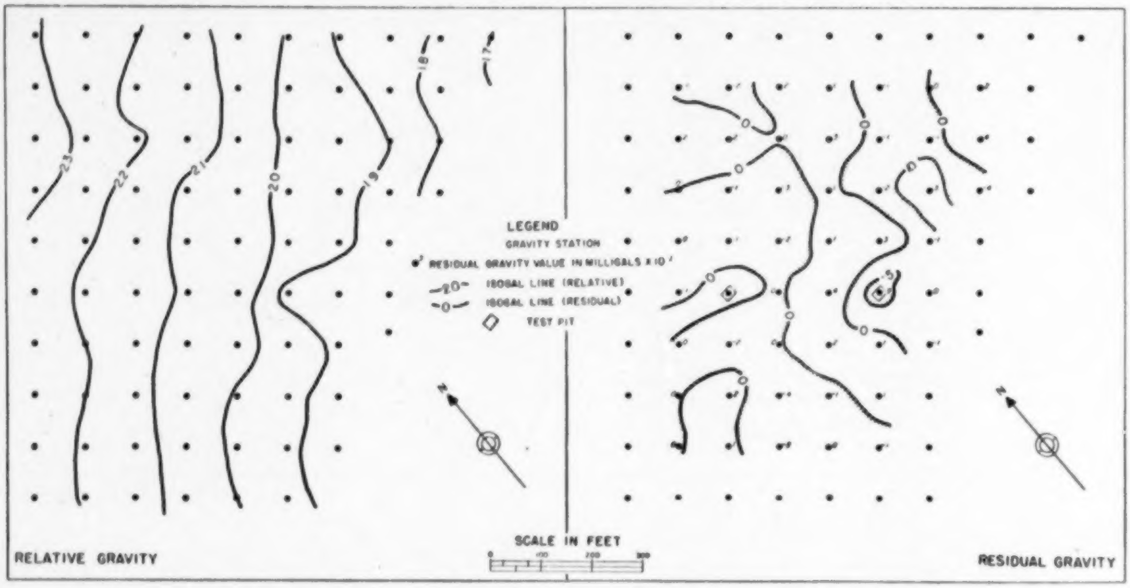

Fig. 6—Relative and residual gravity maps of a non-mineralized area, Washington County, Mo.

non-commercial deposits there was also some correlation between positive residual gravity anomalies and small areas of mineralization; however, these small pods of barite could not be located with much confidence by use of a 100-ft station interval. The graph also indicates that bedrock pinnacles were a significant factor in producing positive residual gravity anomalies.

No large concentrations of barite ore were revealed by the gravity method over the some 525 acres surveyed except that in the Horine tract. Conclusions and recommendations based on gravity observations were corroborated by test pitting. The accumulated data indicate that a large commercial body of residual barite can be outlined and the tonnages therein computed with an expected error of 35 pct or less by use of a gravity survey at proper station intervals, or by returning to increase the station in interesting areas.

The gravity data must be checked by test pitting to determine the cause of a residual gravity anomaly, because these anomalies were found to be attributable to one or more of the following factors: 1—barite mineralization, 2—bedrock pinnacles and knobs, 3—flint-bars, and 4—unknown concentrations of mass and/or probable error.

The results strongly suggest that areas lacking significant positive gravity anomalies are devoid of near-surface barite bodies of commercial size and may be eliminated from further consideration.

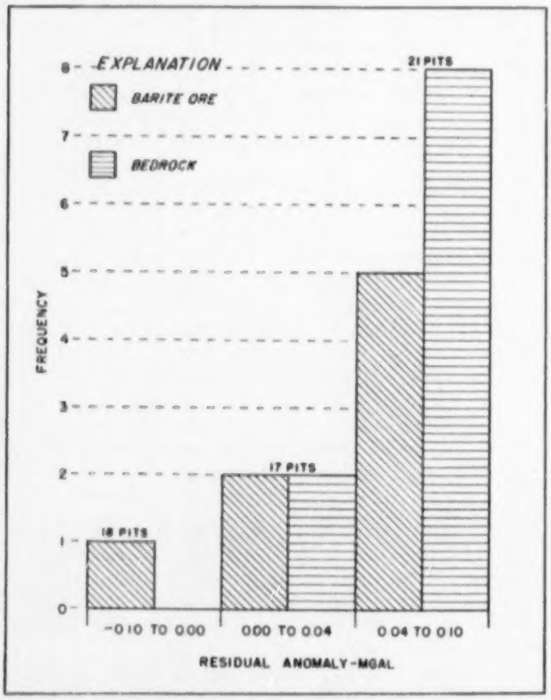

Fig. 7—Bar graph showing correlation between positive residual anomalies and small areas of barite ore, Washington County, Mo.

Acknowledgments

The authors gratefully acknowledge the permission granted by the Baroid Sales Division of the National Lead Co. to present this paper. Also they wish to express appreciation for the mining data and all other information and aid furnished by the Fountain Farm Office of the Baroid Sales Division. The writers are indebted to Rollyn P. Jacobson for the drafting of the illustrations.

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Testing for Copper and Zinc In Canadian Glacial Soils

by C. T. Bischoff

This paper describes the results of testing with colorimetric methods, using "dithizone", soil samples taken over various known copper and zinc deposits covered by glacial till. Variation in results is shown for different depths and types of overburden as well as grade and type of deposit. Limiting factors for the practical application of this work are discussed. The method has proved successful for copper and zinc deposits under clay and fine sand with depths up to at least 30 ft but fails in coarse sand and gravel unless depths are very shallow. Swamps require penetration to the underlying subsoil for sample material.

DURING the past few years geochemical testing for traces of heavy metals in water, soil, rock, and vegetation has aroused increasing interest. Various techniques for field and laboratory determinations have been described in the literature, as have some of the results of application. However, little information has been published regarding application to glacial terrain. Over 90 pct of the Canadian Shield is overburdened, resulting in high costs for mineral exploration once the outcropping ore deposits have been found. This has been largely responsible for the widespread application of mining geophysics in Canada, permitting concentration of effort on area or zones considered most favorable. However, geophysical interpretation has its limitations, since at least 90 pct of the structures indicated thereby contain no valuable minerals. A more direct approach is therefore highly desirable. If underlying base metal mineralization can be detected by sampling soil or vegetation at moderate cost this should prove of great help in locating new discoveries or extending known ones.

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Discussion on this paper, TP 3676L, may be sent (2 copies) to AIME before March 31, 1954. Manuscript, Jan. 26, 1953. Revised Aug. 31, 1953. Los Angeles Meeting, February 1953.

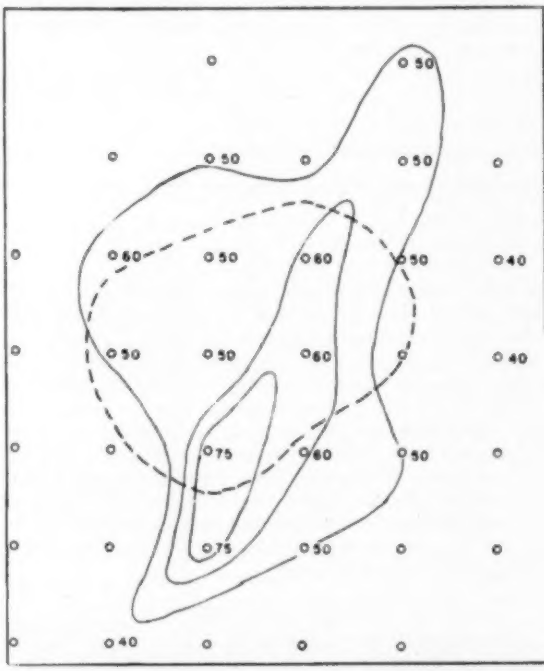
A large proportion of Canadian ore deposits contain appreciable copper or zinc, even where these are not the principal economic metals. Consequently the field of application is a broad one.

This paper deals with investigations along these lines with particular emphasis on soil sampling. The problems involved from the start were:

1—Which types of glacial soil, if any, would best lend themselves to testing, and conversely which types might be considered relatively hopeless?

2—Through what depths of overburden could significant mineralization be detected?

3—What sampling techniques would prove economically applicable? This included minimum depth of sample and maximum spacing that could be allowed.



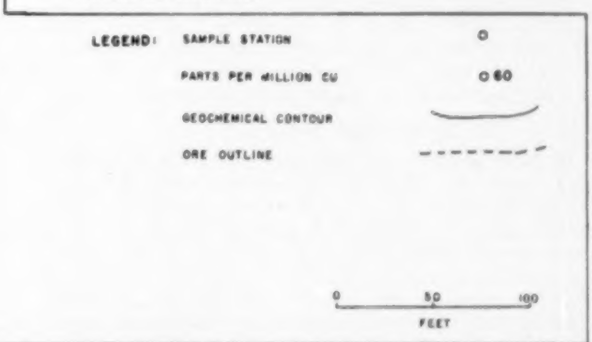


Fig. 1—Geochemical soil test. Overburden: clay, 25 to 35 ft. Mineralization: low-grade, medium-size replacement pyrite, chalcopyrite.

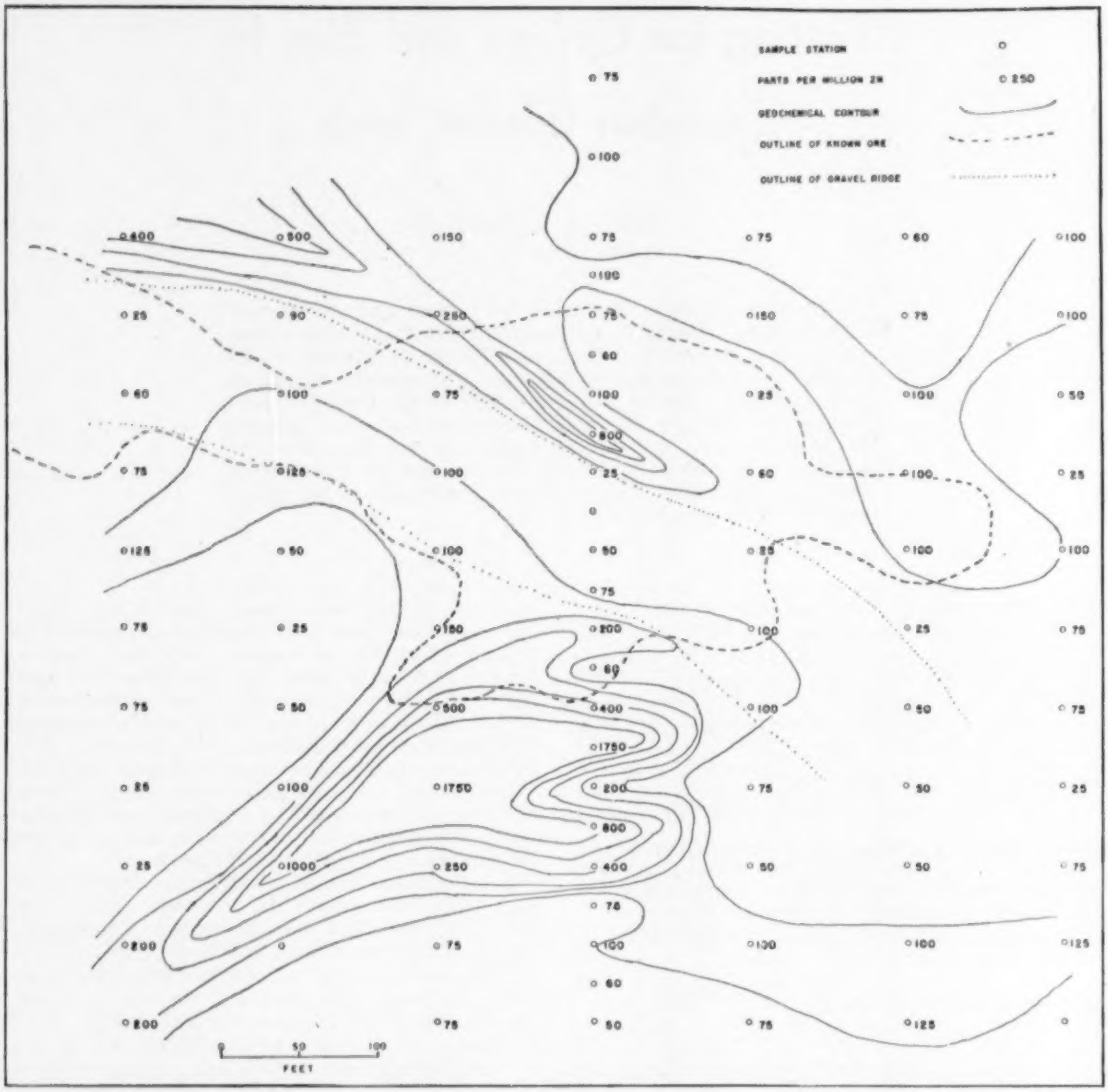


Fig. 2—Geochemical soil test. Overburden: clay, 5 to 20 ft. Mineralization: large, low-grade replacement pyrite, sphalerite. Slope: gently north and south from gravel ridge.

4—How would size of deposit and type of mineralization affect efficiency?

5—What effect might be expected from float and salting by various agents, including drainage, in the way of providing false anomalies not related to underlying or adjacent mineralization?

Soil Types

It soon became apparent that the most favorable soil types were fine-grained homogeneous clay and sand. Note in Fig. 1 the anomaly caused by low-grade copper through 30 ft of clay. Other workers have found shales tend to accumulate heavy metal in trace amounts, and there is a similar tendency in clay. Gravel and coarse sand on the contrary proved very unfavorable, probably because of rapid drainage. Note blanketing effect of sand and gravel ridges in Figs. 2 and 3. Swamps, which are common in the Canadian Shield, proved unfavorable as far as the humus and black muck went. However, it was found that if samples were taken from the underlying clay or sand, results were dependable.

The depth of favorable overburden through which ground water would bring appreciable quantities of heavy metals to surface was surprising. The practical maximum overburden is now considered to be 30 to 50 ft for clay and 20 to 30 ft for fine sand. It has also been found that there is a practical minimum depth required for efficient soil testing. Where the overburden is less than 3 to 5 ft it now appears preferable to test vegetation. More will be said of this later.

Sampling Technique

Samples of surface material have proved erratic under northern conditions and it is better to take subsoil lying below root growth or surface debris. However, in glaciated terrain the subsoil is seldom

more than 1 ft below surface except in swamps, where on one occasion it was necessary to go to a depth of 40 ft below surface.

Spacing requirements depend partly on dimensions of the source (size of deposit) partly on depth of overburden. However, a spacing of 50 ft along lines 300 ft apart is generally adequate for reconnaissance, and there was no occasion to sample closer than 25 ft.

A few ounces of material are plenty for making determinations and reserving a portion for reference. Samples are taken with a short piece of ½-in. pipe welded to the end of a 6-ft rod. This tool is inserted into a hole in the ground made with a length of bar or diamond drill rod forged to a dull point. It is then given a few blows to ensure entry into fresh undisturbed soil. One side of the pipe is ground away so that on insertion of the tool soil passes through until the tool reaches maximum depth. On withdrawal, this deepest material remains in the pipe and can be easily removed into a sample envelope.

Determinations of zinc and copper content of the soil are based on techniques described by Huff, Lakin, and others in publications of the U. S. Geological Survey and in *Economic Geology*. These techniques have been summarized in a compilation by Lakin, Almond & Ward published by the Northwest Mining Association, Spokane, Wash. Methods concerning copper and zinc have been modified considerably in the interests of convenience, speed, and accuracy. However, as the work is commercial and competitive, these modifications cannot yet be described in detail.

It must suffice to say that the color comparisons involved in the usual zinc *dithizone* determinations have been found reliable, provided both dithizone and buffer solutions are pure and fresh. However, it has been discovered that copper is more amenable to a neutral endpoint method. This can be made extremely sensitive if pH control is adequate.

Results can be made to check within 20 pct, and as anomalous values over significant mineralization have been found to be from 3 to 10 times background, such accuracy is adequate.

Parts per million of zinc and/or copper are plotted for each station on a suitable scale and contoured for interpretation.

Where anomalous metal values occur in the soil their pattern almost invariably shows some deformation or drift caused by surface or subsurface drainage. However, in shape, extent, and amplitude they have proved remarkably similar to published results of work in residual soils.

This brings up the interesting question of how much of the results obtained in residual soils may be due to underlying mineralization rather than to original metal content of the soil itself which may have been leached and dissipated. However, as work has been largely confined to transported soils, there is no answer at present.

Effect of Extent and Type of Mineralization

It appears logical that anomalous results found at surface will be proportional to the amount of metal made available through solution and transportation to its present site. Thus a large low-grade deposit will provide more effect than a small high-grade one. Shearing or other fracturing which provides fresh surface and permits access to solutions will increase the effect, and this will be multiplied if pyrite or pyrrhotite are present to provide acid for solution.

Fig. 3 shows results over somewhat lower grade material (with abundant pyrite) than is indicated in Fig. 4. Fig. 4 shows results where relatively high-grade copper (chalcopyrite) ore contains very little pyrite or pyrrhotite.

Deep overburden will disperse the values over a greater area, while a permeable layer of sand or gravel under clay may permit transportation for some distance before metal solutions reach surface. Note in Fig. 5 transportation of values away from the source.

Some difficulty has been experienced in taking satisfactory samples where the surface is covered with boulders or overburden is very shallow. In such cases biogeochemistry should prove more effective.

The experience of the writer and his co-workers with this method has been limited to date, but it appears to have few serious disadvantages. It cannot be recommended over swamps, as the roots of trees do not usually penetrate to the underlying subsoil. Open fields and recent burn fail to provide the necessary trees. However, it can still be applied to a large portion of the potential area of the Canadian Shield. It may prove more efficient than soil testing over coarse sand and gravel as the vegetation may tend to accumulate such solutions as pass through. However, this is only a conjecture so far. Certainly it is more easily applied under winter conditions, when the ground is frozen and soil sampling becomes difficult. Fig. 6 shows the results of sampling birch twigs over and adjacent to low-grade copper and zinc with abundant pyrite and pyrrhotite. Results in ppm zinc in ash are very high, as is characteristic of birch. The lobe of very high values southeast of the shaft is probably due to drainage from the dump. However, high values

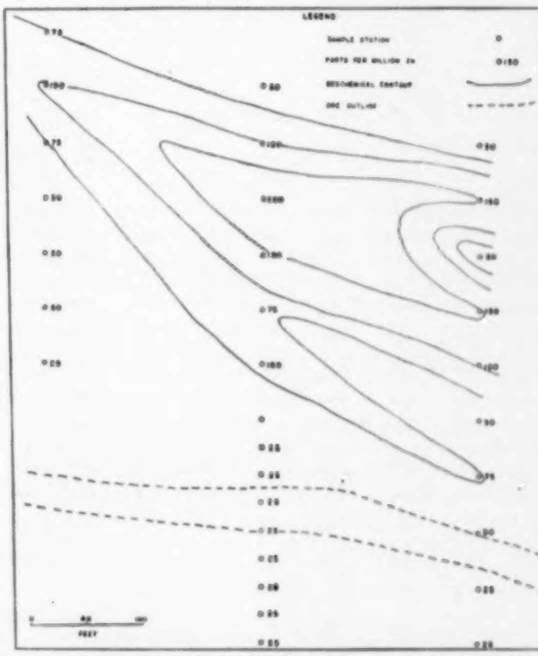


Fig. 3—Geochemical soil test. Overburden: gravel under clay 25 to 35 ft. Mineralization: large, low-grade shear zone, pyrite, sphalerite. Slope: gently north.

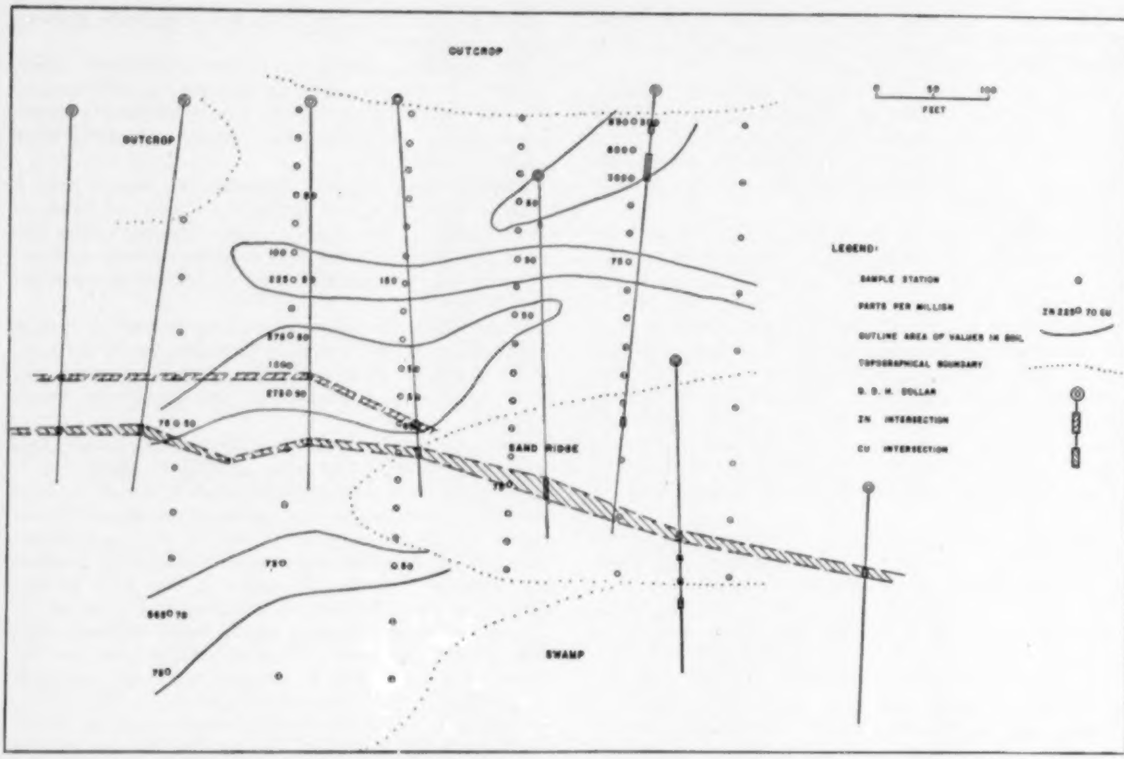


Fig. 4—Geochemical soil test. Overburden: sand, 5 to 40 ft. Mineralization: low-grade, short wide lenses, pyrite, chalcopyrite. Slope: surface, 5 pct south; bedrock, 10 pct south.

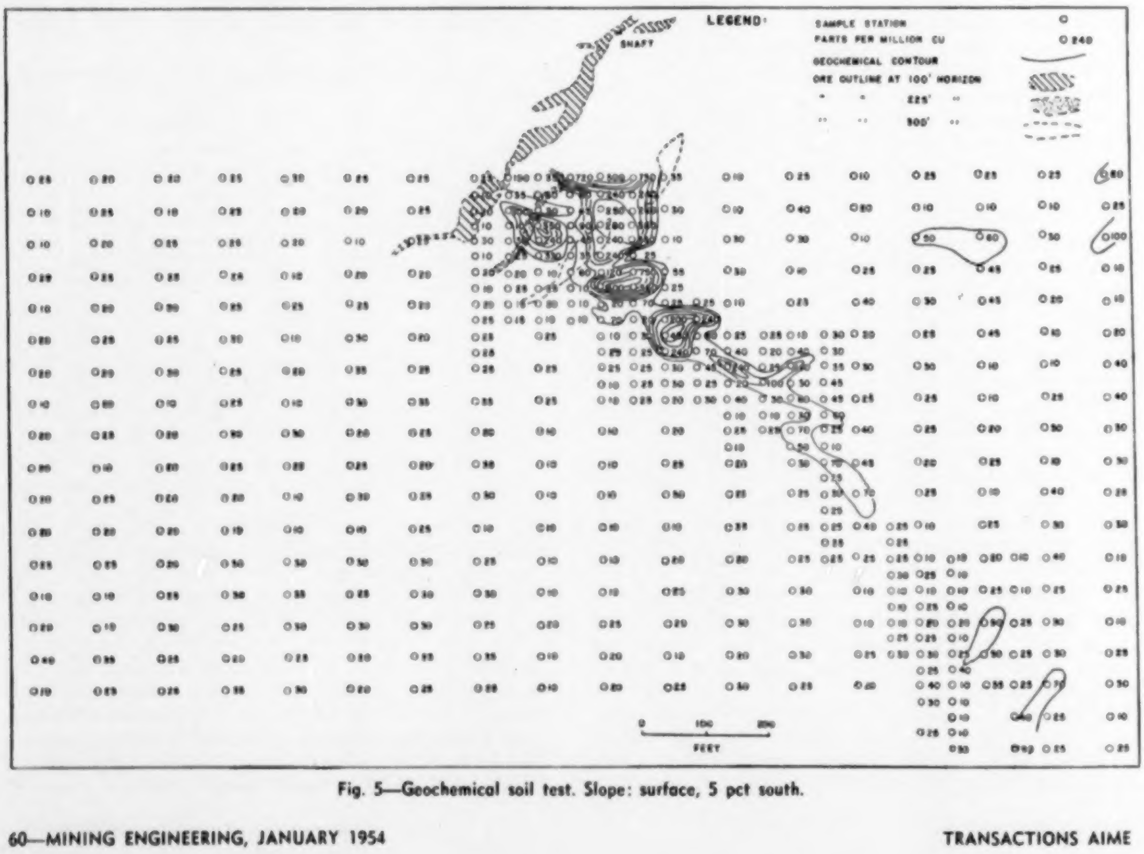


Fig. 5—Geochemical soil test. Slope: surface, 5 pct south.

in the upper left-hand corner cannot be explained by any known occurrence and may indicate additional mineralization.

While various species of trees differ in their affinity for copper or zinc, many species are sufficiently alike to be interchangeable.

Conclusions

Testing of soil and vegetation for traces of heavy metals in glaciated terrain is quite feasible under certain conditions. The overburden should be fine-grained and of moderate depth. Swamps may be sampled if the underlying subsoil can be reached. Type and size of mineralized structure as well as type and depth of overburden must be considered in assessing the applicability of the method. The ranges of anomalous values found over or near significant mineralization are usually three to ten times background, permitting colorimetric analyses to be applied.

Biogeochemistry may be substituted for soil testing except over swamps and may prove more efficient in the case of poor surface conditions or winter operations.

As is the case in geophysical work, relatively large areas should be covered by a pattern of samples, so that a picture of heavy metal distribution may be obtained. A few scattered samples can have little value and may be quite misleading.

In general geochemical techniques are more laborious on a per reading basis than most geophysical methods. Consequently they tend to be more expensive. Some very optimistic cost figures have been set forth in some publications on this subject. However, these appear to exclude indirect costs such as research, supervision, and interpretation of results, which are important items.

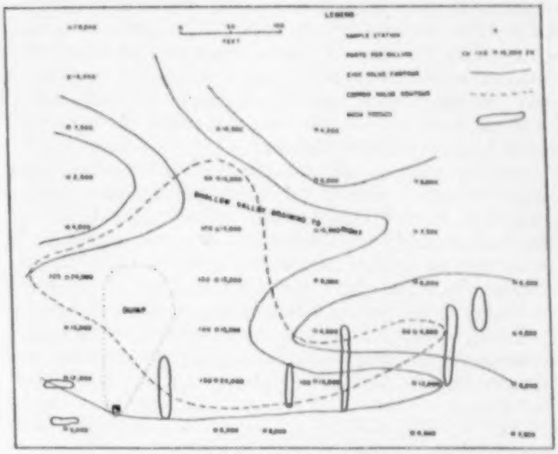


Fig. 6—Biogeochemical test. Samples: white birch, second year stems. Overburden: clay, 0 to 20 ft. Mineralization: replacement lenses are pyrite, pyrrhotite, chalcopyrite, sphalerite.

Consequently these techniques may find their best application in checking of geophysical anomalies and apparently favorable geological structures. Nevertheless, there are some conditions under which geophysical methods are quite ineffective, not to say misleading, and in such cases geochemical prospecting may provide a more efficient means of searching for buried ore deposits.

Trackless Development of an Inclined Limestone Deposit

by R. W. Jenkins

TRACKLESS equipment is being used by the Coplay Cement Manufacturing Co. to develop a folded limestone deposit economically and safely with inexperienced men. Cost and quality of development stone results in a saving when it is used instead of outside sources of limestone. This favorable cost has been attained by following a methods development and training program described in this paper. It is expected that further savings in favor of the mined stone will be made when stopes now being prepared are in production. The present equipment will be used for loading from stope draw points.

The limestone is blended with quarried *cement rock* to serve as raw material for Portland cement, first produced in this country by Coplay Cement Manufacturing Co. from a process developed by its president, David O. Saylor, in 1873. For many years the cement rock alone or with a small amount of added limestone was used for raw materials. Later as specifications were raised and the richer portions of quarries were depleted, limestone from outside sources was required in increasing amounts. In 1925 D. J. Uhle, the general manager, began to prospect company property for limestone.

It was known that the argillaceous cement rock was underlain by crystalline high calcium limestone. After an extensive drilling program it was found that there were large reserves of limestone underlying a recumbent syncline exposed in the south wall of the company's No. 3 cement rock quarry. A quarry was started on the vertical limb of this fold in 1927, and by 1930 the full requirement of the plant was met.

After 1945 production diminished because of the occurrence of dolomite beds in the south wall. The quarry floor was then 135 ft below the cement rock level and 285 ft below surface. In 1949 Gerald F.

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Discussion on this paper, TP 3387AH, may be sent (2 copies) to AIME before March 31, 1954. Manuscript, Feb. 25, 1952. New York Meeting, February 1952.

Sherman, engaged as consulting engineer to determine the feasibility of mining the limestone remaining in the quarry walls, advised that there appeared to be large reserves of mineable limestone and recommended opening a level on the lowest quarry floor to prospect and develop the exposed beds by trackless equipment.

In December 1949, 100 ft of experimental drift were driven with a truck-mounted jumbo, a front-end loader, and 5-yd quarry trucks. The program indicated that the optimum size of heading was 24 ft wide and 12 ft high, this heading width requiring no support and the back being low enough to be easily scaled and inspected. The folding made both breaking and scaling more difficult than that usually encountered in flat-bedded deposits, but drifting indicated that rock could be produced, and at a lower development cost than for outside sources of limestone. It was decided to purchase equipment and proceed with a development program.

A reconditioned Joy 16HR, 440-v ac loader with a gooseneck conveyor for truck loading was purchased. A Joy 60E12 diesel-electric shuttle car was ordered and arrangements were made to use 5-yd trucks until it was delivered. A truck jumbo equipped with two hydro-drill jibs with 6-ft chain feeds and 3½-in. drifters was on hand. Seven-ton skips hoisting in balance to the crusher on the cement rock level were available from the previous quarrying. The rock was to be blended with the cement rock as evenly as possible at the crusher. About 1000 tons of cement rock were crushed per day; experience had indicated that this allowed 300 tons of limestone per day to be hoisted from the mine.

The development headings were laid out to follow the limestone beds exposed in the quarry walls. To maintain the highest possible grade, strike fault zones and dolomite beds were left in pillars and crosscut only where needed for access and ventilation. The structure was rolling and plunging and it was necessary to follow the contacts closely to break clean limestone. These proved to be too obscure to follow by eye and required sampling each round. Results are posted on 20-scale sample maps.

Mine personnel were selected under the procedure set forth in the contract, the union requiring the classification and posting of all jobs for bidding. Awards were made to the applicants on the basis of seniority, eliminating the possibility of selection or training by promotion. None of the applicants had had any previous mining or quarrying experience. It was apparent that the success of the venture depended on developing simple and safe methods for each job and training the men in their use. The first step was to develop a standardized drilling and blasting method.

Experimental headings had been broken with 12-ft holes drilled in a V pattern. A three-man crew required two shifts to drill and blast, using a dual jib jumbo. The average round, requiring 1.8 lb of powder per ton, broke 160 tons; the average advance was slightly over 6 ft and the efficiency was about 55 pct. A study disclosed that: 1—the men could not properly point the 12-ft holes; 2—where the cut holes were properly drilled the side holes would bootleg from 1½ to 2 ft; 3—the 60 pct dynamite was too fast for the rock; 4—changing steel should be eliminated wherever possible; and 5—the dual jib jumbo was unstable.

The round was shortened to 10-ft cut and 7-ft side holes and the jumbos changed to single jibs. This eliminated 75 pct of the steel changing. A 10-ft pipe with guide bars welded at the cuthole angles centered on the floor at the face was used as a template by the drillers. Five parallel flatback holes were used to eliminate a line of weakness in the back caused by drilling the V cuts all the way up the face. To stimulate the miners' interest, time was taken to discuss each round after blasting. Within a month the drillers had achieved a fair degree of skill in pointing their holes and properly timing the rounds. At this time the company introduced 40 pct Atlas Giant gelatin with a 90-stick count and Rockmaster millisecond delays. An improvement in breaking was noted. The performance when this shorter round was used was 130 tons per round, a powder consumption of 1.3 lb per ton, an advance of 5.5 ft per round, and efficiency of 77 pct. The two-man crew drilled and blasted in two shifts.

It was now felt that the drillers had attained enough skill to permit reduction of the 2-in. diam hole then being used. There was an improvement in drill speed and powder consumption when 1⅝-in. single pass bits were used. Before long, however, there was difficulty with chipped wings and bits lost in the hole, and a change was made to threaded tungsten carbide bits. Because of thread trouble, the company adopted and still uses Rockbit Intraset, with carbides integrally set in alloy steel rods.

To take advantage of the increased drilling speed the round was lengthened by 12-ft cut and 9-ft side holes. Chain feeds were extended to 9-ft runs. This 40-hole round averages 188 tons, an advance of 8 ft, with powder consumption of 0.97 lb per ton and an efficiency of 87 pct. Two men drill and blast two rounds in adjacent headings in three shifts. Part of the reduction in powder consumption is due to the use of three sticks of gelatin in the bottom of each hole with the primer, the balance being gelodyn No. 3, which has a stick count of 120.

Three driller blaster crews now break 300 tons per day besides doing the extra scaling, pipe laying, and toe drilling in the cement rock quarry. The improvement in tons per man shift from 26 to 63 and powder consumption from 1.8 to 0.97 lb per ton indicates that efforts in training the men have been well spent. A future study will determine possibilities of reducing hole diameter to 1⅜ in. and drill steel to 1⅛ in., using smaller machines.

For a year before the shuttle car was delivered, three 5-yd trucks, each hauling one skip load of 7 tons, were required to handle 300 tons per shift. The shuttle car replacing the three trucks hauls two 7½-ton skip loads per trip and there is a wait of 3 to 4 min for the second skip. The car cycle from 1000 ft one way is 12 min: 5 min total travel time, 3 min at the loader, and 4 min at the skip. The two sections of the mine are at different levels connected by grades of 15 pct, which are negotiated without difficulty. Top tonnage to date has been 435 tons from 1000 ft.

Company experience has shown that the diesel electric car combines the best features of the cable reel and the battery-type car. General specifications for this car are very similar to those for the Joy 60E rock type widely used in potash, limestone, and iron mines. The power unit is a General Motors Series 371 diesel, driving a 250-v dc generator. There are three 15-hp series-wound gear motors, two on traction and one driving the conveyor and hydraulic pump for the steering booster. A very effective electric brake is provided in addition to

hydraulic disk brakes on the rear wheels and band brakes on the front wheels. The slower application of voltage by the diesel-electric drive seems to favor the motors, drive chains, and conveyor chains. The absence of a gear shift simplifies driver training.

Hauling over grades has proved that the greatest possibility of a major breakdown is the destruction of the armature by overspeeding. A top speed of 8½ miles per hr has been set by the manufacturer and a warning device is provided. From an operating standpoint, some means of automatically cutting in the electric brake would be more satisfactory. The driver station should also be raised for better visibility in sinuous headings.

The chemical-type exhaust scrubber uses 10 lb of aqueous sodium sulphite and 0.5 lb of hydroquinone in 15 gal of water. As the exhaust gases evaporate the water the level is maintained automatically from a 45-gal makeup tank. The scrubber carries sufficient water and chemical for a full-shift operation. Irritants are not noticeable and the weekly tests of the exhaust gas show less than 0.005 pct CO. In an 8-hr shift 9 gal of fuel are used.

The loader crew consists of a loader operator, a helper, and two scalers. They do all the loading, scaling, and moving and greasing of the loader, which will be used to load from future stopes. There has been some stope preparation and surface loading in high faces to test the performance of the loader under these conditions, revealing the fact that the condition of the floor has more to do with efficiency of the loader than any other factor. As the rounds were broken with smoother floors and more even walls the loader breakdowns decreased. It has been possible to load headings driven on plus or minus 15 pct grades without difficulty.

The size of the headings and frequent breakthroughs to the quarry face have resulted in good natural ventilation in the mine. Joy 5-hp Axivane fans with 18-in. vent tubing provide additional ventilation in the most advanced headings. The mine air is tested weekly with a CO detector.

The training and safety program has removed the prejudice originally held by the employees against mining. The turnover is low and there is no difficulty in obtaining replacements. The largest safety problem at the start was to build the confidence of the men by training them to feel that if they followed safe working practices they were in no danger. For this reason the safety features of the new methods were consistently stressed rather than the efficiency. The two years without a lost time accident confirm the correctness of this approach. The two unusual hazards for inexperienced men were explosives and falling ground. Strict supervision of explosives handling and blasting practice is possible in a small operation. Loose ground is more difficult to check; each man, therefore, is trained in scaling when he starts in the mine, and it is emphasized that he is responsible for the place in which he works. Two scalers are carried on the crew to make sure all new blasts will be scaled. This is a high proportion of man hours devoted to scaling, but an early accident would seriously have jeopardized the future of the mine and the company's investment.

Table I. Operating Statistics for Trackless Equipment

Tons per day	300	Holes per round	40
Active headings	14	Tons per round	188
Jumbos	3	Lb per ton explosives	0.97
Driller-blasters	6	Tons per jumbo shift	126
Loader crew	2	Tons per driller shift	63
Scalers	2		
Shuttle car	1		
Total no. of men	11		
Tons per man hour	3.2		

Since the mine is primarily on a development basis it has not been possible to set up a panel system with a definite cycle of operations. However, it has been found economical to follow certain rules in organizing this work: 1—Headings should be driven in groups of two or more to save setting-up time for the jumbos and loaders. 2—A ratio should be maintained of 4 active headings to each jumbo. 3—All new conditions that arise should be carefully studied, methods developed, and the men carefully instructed in the mine, with the emphasis on safety.

Table I summarizes present operating statistics.

Acknowledgments

The writer wishes to acknowledge the kind permission given by M. E. Grunewald, President, and D. J. Uhle, Vice President and General Manager, to publish this paper. He wishes also to acknowledge the assistance given by A. F. Rambosek, Chief Engineer, and L. M. Yarberry, Mine Superintendent.

The Brown Iron Ore Resources of Missouri

by Edward L. Clark and Garrett A. Muilenburg

THE first record of the discovery of iron ore in Missouri was Marquette's observation in 1673 of brown iron ore, or limonite, in the Mississippi River bluffs just north of the mouth of Apple Creek in southeastern Perry County. There is no record of any attempt to mine or smelt Missouri iron ores until 1815, when the Ashebran furnace was erected at the Stouts Creek shut-in near Arcadia, Iron County. Some limonite was treated in this furnace, the first iron furnace west of Ohio, but most of the ore was hematite from Shepherd Mountain and adjacent deposits. Eight years later, in 1823, the Perry furnace five miles north of Caledonia, Washington County, was constructed to smelt limonite ore. It

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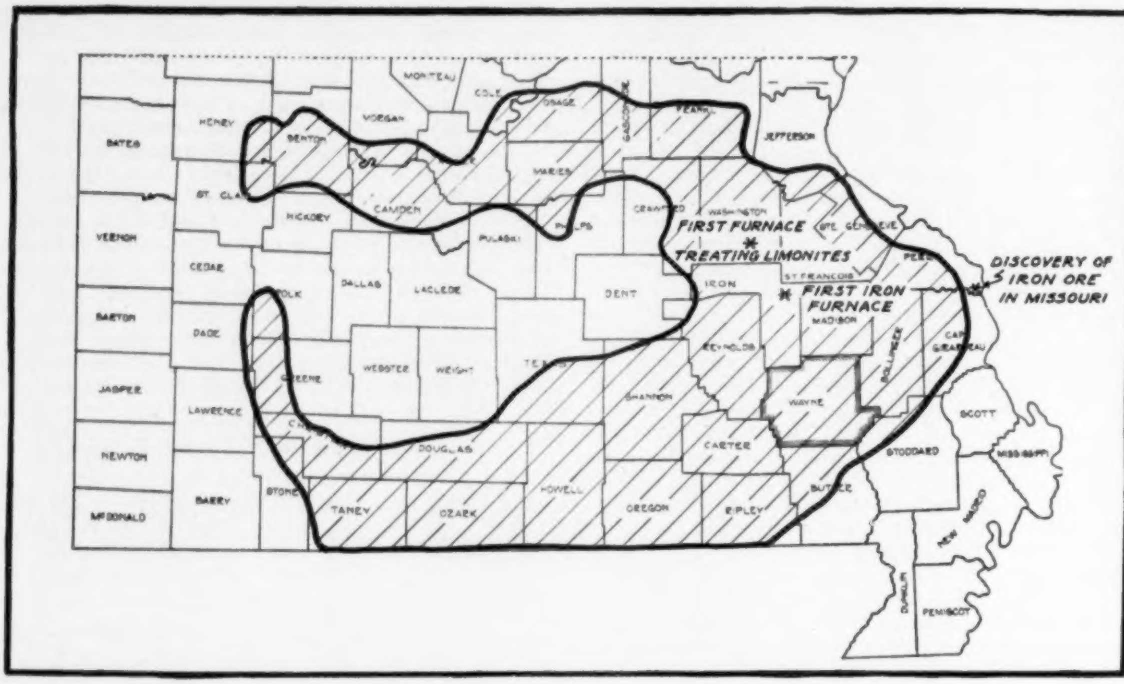

Fig. 1—Distribution of limonite ores in southern Missouri.

was not until 1890 to 1900, however, that these ores attracted considerable attention. Nearly 300,000 tons had been produced by 1911, and this production had come from 24 counties in the Ozark region. For the next two decades, until 1931, essentially all activities ceased. During the depression years of the thirties when employment was low many people turned to the brown ores for subsistence; consequently production was increased. World War II produced another stimulus to the industry. The availability of risk capital in the past three years has revived interest in these deposits, although no appreciable increase in production has resulted.

Character of the Deposits

On the basis of their possible origin, Crane[1] divided the limonites of Missouri into two classes. Deposits that had been derived by oxidation and hydration of marcasite and pyrite were termed secondary, and those precipitated directly as hydrous ferric oxide from solution, much as bog ore would be formed, were termed primary. It has been difficult for the present writers to distinguish these classes on the basis of the physical character of the ore. There is, however, a sharp distinction in mode of occurrence of the two types or classes in southeastern Missouri. The secondary limonites bear no relation to topographic conditions except that they are more frequently exposed on slopes where there has been active erosion. The primary limonites of Crane, on the other hand, are found on or near the crests of the ridges and divides adjacent to and in the Gulf Coast embayment of southeastern Missouri. In a local area the primary deposits have common elevations, with a regional dip toward the southeast.

The individual deposits, or *banks*, vary greatly in size and outline. Those associated with limestone, dolomite, and solution breccia are usually small and contain only a few tons of ore. The deposits in the residuum may be large, but with few exceptions individual deposits have not exceeded 75,000 tons. The majority of the banks are rarely more than 75 ft across and 35 ft deep, and relatively few pits have a long axis greater than 150 ft.

On the surface the exposures are attractive, and the ore appears to be all over the ground, its resistant character having caused it to concentrate in the upper soils. Because of the high specific gravity of the limonite masses the ore is left behind as lighter fractions of the residuum and bedrock are eroded away. The tendency for the ore to creep or move downslope always exaggerates the amount present. In some areas there were literally hundreds of tons of such boulders on an acre of ground. When mining got under way and these surface boulders had been recovered, the actual size of the deposit became greatly restricted, and in many instances there was no underlying orebody. The close proximity of one pit to another has often misled the prospector and miner to believe they are connected and continuous over large areas. Such interpretations are followed by the speculator or promoter.

Character of the Ores

The brown ore consists predominantly of limonite. Small amounts of hematite and goethite may be present. The gangue consists of chert fragments, clay, silica sand grains, and iron sulphides, both marcasite and pyrite. Quartz along fracture planes and vugs may be present. In many occurrences brecciated masses and individual fragments of chert are so abundant as to prohibit exploitation. The cellular porous ores usually carry much clay that must be washed out before shipment. Some large boulders of ore contain cores of unoxidized pyrite and marcasite. These sulphides normally increase in depth,

but they have been observed in large residual boulders of weathered ore on the surface.

On the basis of physical character the limonite can be divided into five classes: hard dense boulder ore, cellular or cindery boulder ore, tabular ore, stalactitic or pipe ore, and soft granular or ocherous ore. The dense boulder variety has constituted most of the production. Surface expressions of a deposit are usually the hard boulder, tabular, or stalactitic varieties of ore. The apparent light weight of the cellular boulder ore and the soft earthy character of the ocherous ore have undoubtedly caused some potential deposits to be ignored.

Botryoidal structure is prevalent in the tabular variety where it has been developed on the unfilled portion of a vein or large solution opening. Such structures have led the prospector to believe he is near the mother lode because the limonite appears to have been solidified from a molten mass.

Geological Occurrence and Geographic Distribution

Most of the production has come from the residuum from the Potosi, Eminence, Gasconade, Roubidoux, and Jefferson City formations of Cambro-Ordivician age. In southwestern Missouri the ore is related to the erosional surface between Mississippian limestone and Pennsylvanian shale or sandstone. However, small deposits are so common throughout southern Missouri that they may be expected in residuum from any stratigraphic unit between the pre-Cambrian and the Pennsylvanian. Attempts to assign occurrences in a given geographic area to a definite restricted stratigraphic zone have not been successful.

Occurrences of limonite deposits are known in every county in the Ozark region, the adjacent Springfield plain on the western slope, and the adjacent counties in the Gulf Coast embayment, see Fig. 1. Although the distribution is widespread, occurrences are concentrated in an arcuate belt that extends from west-central Missouri eastward to the southeastern part of the Ozark Mountains, then westward to the southwestern corner of the state. Scattered deposits occur in the central area, but the degree of concentration is appreciably less. Wayne, Butler, Howell, Shannon, Ripley, Oregon, Christian, Greene, Madison, and Stoddard counties have contributed approximately 90 pct of the total production.

Exploration

Most of the deposits in Missouri have been placed in production with very little if any exploration. Under these conditions production continued until the ore was depleted or had reached such a grade as to prohibit economical recovery. In brief, exploration was actually mining.

In 1943 and 1944 the U. S. Bureau of Mines examined many surface expressions of possible deposits. Nine were selected for detailed exploration.[2] Rotary-bucket drilling, power augering, test pitting, with shafts, and bulldozer trenching were employed. For the deeper exploration the rotary-bucket drill was adequate and depths of 50 ft were reached with a 16-in. bucket. The advantage of this method over other drilling methods is the large amount of sample obtained and the large size of fragments in the sample. The power-auger was able to reach depths up to 100 ft, but the great amount of chert caused excessive wear on the cutting heads and the spiral flights.

Table I shows the extent of combined exploration on the nine deposits investigated.

The ore developed by this exploration program totaled 91,000 tons averaging 37.4 pct iron. The ore reserves developed on the individual deposits ranged from 0 to 40,000 tons.

Mining and Beneficiation

The brown iron ores present a difficult problem in mining under present conditions. Inasmuch as the deposits are relatively small it has not been economically feasible to attempt large-scale production. Several deposits in a given area may be operated as a unit by providing each one with the necessary loading and hauling equipment and washing and concentrating at a central plant.

Table I. Exploration of Nine Deposits in Southeast Missouri

Type of Exploration	Holes or Cuts, No.	Depth of Penetration
Bucket-drill	105	2424 ft
Bulldozer	6	1000 cu yd
Power auger	34	1089 ft
Test pits	21	218 ft
Total	166	3731 ft 1000 cu yd

When production was at the maximum much hand labor was employed. In some mines, where conditions were suitable, power-operated scrapers and shovels were used but even when such power equipment was used much ore was hand sorted. Such methods produced a grade of ore that would assay from 54 to 56 pct iron. Hand labor is no longer available in the brown ore region and present methods are entirely mechanical. Bulldozers are used for clearing and stripping the ground and power shovels or draglines load the dirt into trucks for hauling to the concentration plant.

Concentration consists almost entirely of washing in a log washer to remove the clay, which constitutes one of the chief impurities. The mine-run ore is dumped on a grizzly usually constructed of old rails, and washed into the log washer with a stream of water from a high-pressure hose. Large chert boulders and other waste are removed from the

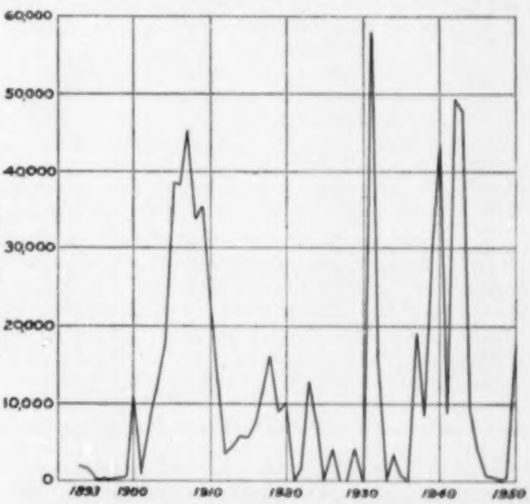

Fig. 2—Brown iron ore produced in Missouri. (After Bishop, *The Mineral Industry in Missouri in 1946 and 1947.*[5])

grizzly by hand. The overflow from the logs goes to a settling pond for removal of solids, and the cleared water is recirculated. The discharge from the head of the logs is passed over a wet screen from which the undersize material goes to the ore bin and the oversize to a crusher. Some oversize chert is picked from the conveyor before it reaches the crusher. If the ore contains too much silica to meet the minimum specifications for iron content, it must be removed. Jigs of various types have been used to remove excess chert, but no standard practice has been worked out. Differential settling in a heavy medium has not been tried in practice. A pilot plant is now using a spiral classifier for the logs.

A water supply of ample capacity and the disposal of waste are serious problems in a washing operation. The ratio of waste to ore varies considerably from one deposit to another and the size of the settling area required will be proportional to the size of the deposit and the concentration ratio.

Production

Approximately 700,000 tons of brown ore have been produced, see Table II. Although the total tonnage is small it has been significant in the economy of the areas of production. In many respects it is *poor man's ore*. When difficult times arrived, the individual farmer became an iron miner by picking up surface boulders and hauling them to the nearest railroad. During the depression years of the early thirties, before relief became an accepted policy, it was not uncommon to see small individual stock piles of 5 to 25 tons of ore at each village.

Table II. Annual Production of Brown Iron Ores in Missouri in Long Tons

Year	Brown Ores, Primary and Secondary	Year	Brown Ores, Primary and Secondary
Prior to 1893	26,015	1921	
1893	1,800	1922	1,282
1894	1,220	1923	12,966
1895		1924	7,422
		1925	
1896	60	1926	4,371
1897		1927	
1898		1928	
1899	333	1929	4,155
1900	10,454	1930	315
1901	292	1931	58,233
1902	8,520	1932	15,797
1903	11,574	1933	
1904	17,642	1934	3,704
1905	38,637	1935	126
1906	38,351	1936	
1907	45,367	1937	18,291
1908	33,632	1938	8,331
1909	35,217	1939	29,415
1910	22,542	1940	43,523
1911	12,309	1941	8,738
1912	3,399	1942	49,048
1913	4,125	1943	47,715
1914	5,500	1944	9,050
1915	5,145	1945	4,000
1916	7,346	1946	536
1917	11,393	1947	265
1918	16,013	1948	
1919	8,759	1949	150
1920	9,671	1950	17,500
		Total	720,249

Table II gives the total reported production of limonite that has been shipped to consumers. With shipments being made by scores of individuals, it is not possible to obtain an accurate figure, but figures reported in Table II are believed to be within 10 pct of the total amount that has been mined.

The production of limonite ore has been activated by economic depressions and World Wars I and II. When economic conditions have been good and there was no national crisis or artificial stimulus, production sharply declined, Fig. 2.

Reserves and Future Potential

For the purpose of the following discussion, ore is considered to be material of not less than 35 pct iron, in a physical condition requiring a minimum of concentration to produce a marketable product. Standards for marketable concentrates in the past have been not less than 50 pct iron, dry basis, and not more than 10 pct silica and 0.2 pct sulphur.

Under such standards there are less than 100,000 tons of proved limonite ore reserves in Missouri. The lack of reserves may be attributed to existing exploration and development practices. The character of the individual deposits is not conducive to large exploration or development programs that calculate ore reserves in advance of production. On the other hand, when hundreds of known occurrences are given consideration the inferred ore reserves exceed the total of past production.

Although the total potential reserves are large, they will through necessity be obtained from many individual deposits that may contain no more than 5000 to 25,000 tons. Production schedules will be difficult to establish and maintain unless an organization is operating several deposits simultaneously. There does not appear to be a sufficient reserve available to sustain ferrous metallurgical industries of any appreciable size, especially if such industries are entirely dependent upon local raw materials. It appears more likely that these ores will continue to find their way to markets that need high-quality iron ore low in silica, sulphur, and phosphorous.

New beneficiation processes will be needed to permit mechanization of the mining of these ores. Until such a process is developed, there will be continued waste of potential ore by inefficient treatment, the shipment of a lower grade of concentrate, and the retardation of the development of many potential deposits. A central washing plant treating ore from several mines will permit exploitation that is not realized today. Likewise production can be increased by a program of subsidizing independent contractors with private capital, equipment, and mining experience, followed by a fixed base price on ores shipped, with adjustment of prices after returns have been obtained from the furnace or consumer. Such a program will release the independent operator from the somewhat unsatisfactory treatment he has experienced in the past because he could not maintain a constant grade or quantity of shipping ore.

Although the grade of limonite concentrates produced in Missouri is in demand on the open market, and the potential reserves are large, no large increase in annual production is expected soon.

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Hypothesis for Different Floatabilities of Coals, Carbons, and Hydrocarbon Minerals

by Shiou-Chuan Sun

THE fact that coals of different ranks and even of the same rank differ greatly in their amenability to froth flotation is well known. In recognition of the need for an explanation of this phenomenon, two hypotheses have been suggested. Wilkins[1] reported that the floatability of coals increased with an increase of the carbon content or rank. This postulate is handicapped by the fact that bituminous coals that possess moderate carbon contents are actually more floatable than anthracite coals that have high carbon contents, as shown in columns 6 and 9 of Table I. Taggart and his associates[2] implied that the difference of floatability between bituminous and anthracite coal was caused by the variation of carbon-hydrogen ratio. This is not applicable to the relative floatability of other coals and carbons. For example, column 11 of Table I shows that the carbon-hydrogen ratios of low-floating lignitic coal and non-floating animal charcoal are not only smaller than the moderate-floating anthracite coal, but are also similar to the high-floating bituminous coal. Furthermore, according to this hypothesis, high temperature coke-A (464), Ceylon graphite (1238), and lamp-black (357), all possessing extremely high carbon-hydrogen ratios, should be less floatable than other substances having much lower carbon-hydrogen ratios such as high volatile-B bituminous coal (11.9 to 22), anthracite coal (35.7 to 60.5), lignitic coal (15.6 to 33.6), and charcoal (13 to 26.2). However the former group is actually more floatable than the latter group.

In this paper, a *surface components hypothesis* is proposed to explain the different floatabilities of coals, carbons, and hydrocarbon minerals. The validity of the hypothesis is experimentally supported by the actual floatability, natural floatability, wettability, and adsorbability for neutral oils of coals, carbons, and hydrocarbon minerals tested.

The combustible recovery of the flotation results, as used in this paper, was calculated from Eq. 1:

$$R_c = \frac{P\ (100-E_p)\ 100}{F\ (100-E_f)} = \frac{R_w C_p}{C_f} \qquad [1]$$

where R_c is the percent combustible recovery; F and P are, respectively, the weight of feed and the weight of concentrate or product; E_f and E_p are, respectively, the total percent of ash plus moisture in feed and in concentrate; R_w is the percent weight recovery; and C_f and C_p are, respectively, the percent of combustible in feed and in concentrate. Except for ash and moisture content, all chemical components of a coal are assumed combustible.

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The experimental work included studies on flotation, ultimate and proximate analyses, contact angle tests, extractions of bitumen-A with benzene, adsorptions for liquid hydrocarbons, and wetting tests. Most of the flotation experiments were performed in a laboratory Fagergren machine; others were tested in a small Denver machine. The solid feed for the former was 300 g and for the latter was 30 g. The solid materials used for flotation were crushed to −48 mesh. After the mineral pulp in the flotation cell was agitated for 6 min and the pH was adjusted to 7.5 ± 0.2 with sodium hydroxide or hydrochloric acid, a petroleum light oil having a viscosity of 5.73 centipoises at 77°F was added and conditioned for 2 min. Finally, pine oil was introduced and the froth was collected for exactly 3 min. The weight ratio of petroleum light oil to pine oil was kept constant at 1.5 to 1. Tap water was used for all flotation tests.

Contact angles were measured with a captive bubble machine. For each coal sample, three specimens were mounted in transoptic mounts and polished with levigated alumina, first on a sheet glass, then on a cloth-covered metal polishing wheel. The polished specimen was first washed with distilled water and wiped thoroughly on a cleaned linen pad, then transferred into the pyrex cell of the captive bubble machine and conditioned for 6 min., and finally measured for contact angles at three or more points. Except where otherwise stated, the induction time for each measurement was 1 min. The contact angle representing each material was obtained by averaging the measurements of three specimens. The linen pad was first washed with warm distilled water, then boiled 30 min in a 2N sodium hydroxide solution, and finally washed with distilled water until no trace of sodium hydroxide could be detected in the decanted solution. The cleaned linen pad was stored under distilled water. Immediately before using, the pad was rewashed and transferred into a clean pyrex petri dish partly filled with distilled water. The glassware and rubber gloves used were cleaned by soaking in sulphuric acid-potassium dichromate cleaning solution, followed by rinsing with distilled water. The polished specimens were handled only by glass forceps.

The ultimate and proximate analyses were made in accordance with the ASTM standard procedures for coal and coke. The extractable bitumen-A was determined by weighing 1 g of −100 mesh sample and placing it in a desiccated and weighed ASTM aluminum-extraction thimble. The thimble was placed in condenser hooks and inserted into an extraction flask containing 100 cu cm of benzene. The flask was heated and the benzene vapor was condensed by water coils. At the end of 24 hr of percolation, the thimble was removed, desiccated, and weighed. Loss in weight of sample was taken as bitumen-A and calculated to dry and ash-free basis.

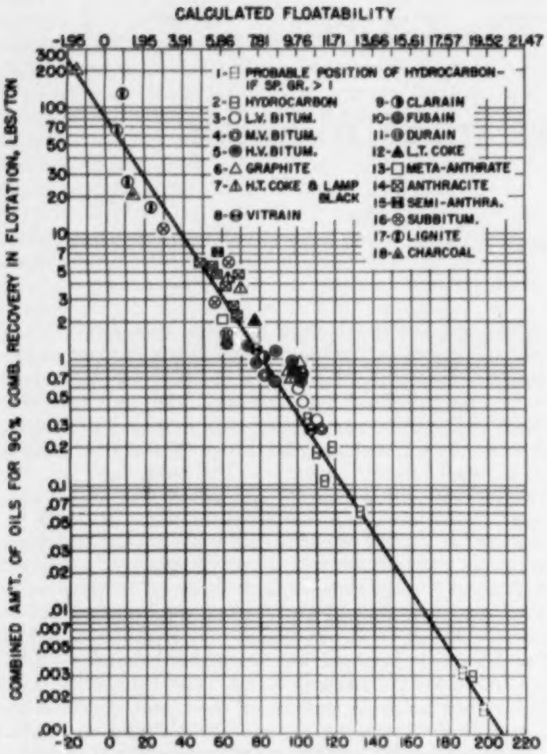

Fig. 1—Correlation between the actual floatability and the calculated floatability index of coals, cokes, and hydrocarbon minerals.

The adsorbability of materials for liquid hydrocarbons was determined according to the following steps: 1—The sized 48x65 mesh material was washed, dried, and stored in a clean desiccator. 2—A 5-g sample was accurately weighed and transferred into a cassia flask having a graduated neck and a ground-glass stopper. 3—After the addition of 40 cc of distilled water, the flask was shaken for 20 min and allowed to stand for 12 hr. 4—Five cubic centimeters of liquid hydrocarbon were added and the flask was shaken for 10 min. 5—The mineral pulp was transferred into a pyrex fritted Gooch crucible and filtered for 1 hr by a water aspirater. 6—The sample, together with the Gooch crucible, was desiccated for a predetermined time and weighed. 7—The difference between the weight of the hydrocarbon-treated sample and that of the original sample was calculated and considered to be the amount of liquid hydrocarbon adsorbed by the sample. 8—The result was further checked by means of ether extraction of liquid hydrocarbon from the filtrate. The time required for desiccation was predetermined by the same procedure given in steps 1 to 6 except that liquid hydrocarbon was omitted, and the sample was kept in a desiccator and weighed after each 20-min interval until its original weight was reached. The amount of liquid hydrocarbons adsorbed by the crucible itself was also predetermined, and the data were taken into account during the calculations of step 7. Obviously the analytical results are only approximately correct.

The wettability of various minerals in distilled water was determined by using 48x65 mesh quartz as a standard particle size. The equal-settling particle sizes[3] of other minerals were calculated and prepared by screening. The sized particles were thoroughly cleaned, washed, dried, and stored in clean glass jars. For each test, 1 g of the sample was spread on the surface of 250-cu cm distilled water in a 400-cu cm pyrex beaker. The water was then stirred gently by a glass rod rotating at a constant speed of 100 rpm. The time required for approximately 95 pct of particles to fall below the water surface was taken as a measure of its wettability.

Surface Components Hypothesis

A surface components hypothesis is proposed to explain the different floatabilities of various coals, carbons, and hydrocarbon minerals. The gist of the hypothesis is that these heterogeneous materials consist of both floatable and non-floatable chemical constituents and that their floatabilities are governed by the balance between these two groups of components. The surface of one material predominating with floatable components is more floatable than that of another material predominating with non-floatable components. The floatable components are oil-avid and water-repellent, whereas the non-floatable components are water-avid and oil-repellent.

Natural coal is generally believed to be a chemical and physical mixture of hydrogen, carbon, sulphur, oxygen, moisture, mineral matter, and nitrogen. The flotation properties of these components can be roughly estimated from the test data of Tables I, III, and IV. For example, the hydrogen content of coal on dry and ash-free basis is believed to be tied up in the form of hydrocarbon[4,5,6a,7] and should be treated as such. Tables III and IV show that hydrocarbons, as represented by wood rosin and beeswax, are water-repellent and oil-avid and consequently should be highly floatable. This is proved to be true by the test data of Table I. In a similar way crystalline carbon, represented by Ceylon graphite and purified spectrographic electrode, is estimated to be moderately floatable; and sulphur,[6b] represented by an average of the floatable element sulphur and the non-floatable pyrite, is considered to be slightly floatable. The unfloatability of moisture, oxygen, and mineral matter can be visualized from Tables I and IV. Table I shows that the non-floatable lignite and animal charcoal are characterized by their high contents of moisture, oxygen, and mineral matter. The deleterious effect of oxygen on the floatability of coals and coke has been described in a separate treatise.[8] Table IV shows that the adsorbability for kerosene of lignite, oxidized coal, and mineral matter, which is represented by slate, calcite, pyrite, and quartz, is extremely low as compared with other tested materials. Owing to the lack of sufficient information,[6c,9] nitrogen is tentatively considered as being slightly non-floatable. Tests 13-16 of Table III show that the contact angle of a high purity graphite stick decreases slightly after being nitrogenated at 1100°C for 5 hr and then cooled to room temperature in the porcelain tube of a Globar furnace. Throughout the heating and cooling a stream of purified nitrogen gas was passed through the tube. A detailed description of the furnace and procedure for making nitrogenous graphite has been reported by Walker.[10] Judging from these tests and the uniformly low content of nitrogen in the tested coals, the role played by nitrogen is relatively unimportant as compared with other components. The above classification of the flotation

Table I. The Ultimate Chemical Analysis, Floatability Index, Actual Floatability, Carbon-Hydrogen Ratio, Contact Angle, Extraction of Bitumen A, Calorific Value, and Specific Gravity of Coals, Carbons, and Hydrocarbons

Test No.	Sample	Ultimate Analysis, Pct — As-Received Basis — H_2O (1)	Ash (2)	Dry and Ash-Free Basis — O (3)	N (4)	S (5)	C (6)	H (7)	Calculated Floatability (8)	Calculated Floatability Index (Using Ceylon Graphite As Standard) (9)	Combined Amount of Petroleum Light Oil and Pine Oil for 90 Pct Comb. Rec. in Flotation, Lb per Ton (10)	Carbon-hydrogen Ratio, Dry and Ash-Free (11)	Average Contact Angle in Distilled Water (12)	Extraction of Bitumen-A with Benzene, Pct Dry and Ash-Free (13)	Sp Gr (14)
1	Petroleum Light Oil, Bradford, Pa.	0	0	0.49	0	0.01	85.4	14.1	23.83	243.2	na.f.	6.1			0.82
2	Kerosene	0	0	0.8	0	0.08	85.5	13.61	23.09	235.6	na.f.	6.3			0.72
3	Pure White Bees-wax, E. & A. Co.	0.09	0.02	6.17	0.04	0	80.2	13.4	21.36	217.9	na.f.	6.0	109		<1
4	American Montan Wax-c	—	0.03	7.95	0	0.3	79.5	12.25	19.38	197.7	na.f.	6.5	105		<1
5	Uintahite (Gilsonite), Utah	0.3	0.19	1.15	2.11	0.52	85.4	10.51	18.48	188.6	0.003[a]	8.1	90	99.9	1.07
6	Wurtzilite, Utah	0.62	0.69	2.46	1.93	3.75	80.6	10.68	18.16	185.3	na.f.	7.6			<1
7	Wood Rosin-K, Hercules	0	0	17.44	—	0.06	73.5	9.0	12.52	127.8	0.06[b]	8.2	70		1.07
8	Resin-600°C, Allied Chem. & Dye	0.1	0.2	1.212	1.5	0.71	91.6	5.0	11.19	114.2	0.10[b]	18.3	50	93.0	1.11
9	Hard Pitch, Allied Chem. & Dye	0	0.1	1.2	1.0	0.5	93.0	4.1	10.05	102.5	0.17[b]	22.7	39	43.0	1.23
10	Tasmanite, Australia	0.8	60.92	7.97	0	4.54	75.0	10.48	11.51	117.5	0.20[b]	7.2	51	3.9	1.36
11	Vitrain (m.v.), Springdale, Pa.	0.8	5.29	3.67	1.39	0.91	88.3	5.12	10.51	107.2	0.29[b]	17.2	49	0.2	1.23
12	M.v. bitum., Hastings, Pa.	0.63	6.3	4.34	1.5	0.88	88.3	5.29	10.64	108.6	0.31	16.7	62	u.d.	1.25
13	Torbanite, New South Wales	0.3	14.77	6.41	0.94	0.78	83.2	8.33	10.54	107.6	0.32[b]	8.2	57	1.2	1.19
14	L.v. bitum., Bedford, Pa.	0.35	8.0	1.19	1.56	1.77	90.9	4.58	10.51	107.2	0.32	19.8		tr.	1.3
15	L.v. bitum., Broad Top, Pa.	0.3	3.0	2.62	1.35	0.91	90.4	4.72	10.38	105.9	0.34	19.1	63	0.2	1.27
16	L.v. bitum., Windber, Pa.	0.6	7.8	2.92	1.58	1.36	89.6	4.54	9.96	101.6	0.47	19.8		tr.	1.32
17	L.v. bitum., Cresson, Pa.	0.6	5.2	3.94	1.43	0.61	89.4	4.62	9.85	100.5	0.65	19.4	60	u.d.	1.28
18	Fusain (m.v.), Springdale, Pa.	0.6	2.57	1.58	0.72	0.87	93.2	3.20	8.61	87.9	0.67[b]	37.3	24	0.5	1.38
19	H.v.-A bitum., Boone County, W. Va.	0.88	7.5	5.49	1.42	0.67	86.2	5.26	10.19	104.0	0.68	15.9		0.5	1.21
20	H.t. coke-A, Phila., Pa.	0.04	10.0	1.54	0	0.65	97.6	0.21	9.61	98.1	0.72	464.0			1.73
21	Lamp black (Martin), Spear Carbon	0.14	0.14	2.07	0.03	1.13	96.5	0.27	9.49	96.9	0.75	357.0		1.2	1.51
22	M.v. bitum., Sabinas, Mexico	0.38	22.2	4.86	1.42	2.14	86.3	5.28	7.95	81.1	0.75	16.3	45	u.d.	1.38
23	H.v.-B bitum., Stockton, Utah[a]	2.0	8.8	8.79	1.33	1.01	82.0	6.87	11.27	114.8	0.78	11.9	39	8.6	1.21
24	Vitrain (h.v.-A), Pikeville, Ky.	1.6	4.84	5.74	1.39	0.76	85.0	5.37	10.08	102.9	0.82[b]	15.8	55	0.2	1.26
25	Graphite, Colombo, Ceylon	0.03	2.18	0.83	0.06	0.11	99.0	0.08	9.80	100.0	0.90	1238.0	35	u.d.	2.21
26	H.v.-B bitum., Clariton, Pa.	1.1	8.47	6.53	1.44	1.31	83.9	5.18	9.81	100.1	0.91[b]	15.7		u.d.	1.37
27	H.v.-A bitum., Richmond, W. Va.	1.22	14.57	2.79	1.62	1.52	87.2	5.54	8.46	86.3	0.94	15.7	35	0.5	1.25
28	Clarain (h.v.-B), Ill.	3.0	4.1	12.13	1.29	2.53	78.5	5.24	7.92	80.8	1.08	15.0	45	2.7	1.24
29	H.v.-B bitum., Hopkins, W. Ky.	1.8	6.14	11.25	1.49	3.48	78.4	5.38	8.57	87.5	1.19	14.5		1.3	1.22
30	Vitrain (h.v.-B), Ill.	3.0	4.5	12.2	1.19	3.71	78.1	4.94	7.49	76.4	1.20	15.8	41	2.9	1.21
31	H.v.-B bitum., Panhandle, Pa.	1.1	8.6	14.58	1.67	1.93	77.0	4.82	7.13	72.8	1.26	19.4	37	1.3	1.32
32	Fusain (h.v.-B), Ill.	0.6	26.5	8.2	0.27	2.51	85.3	3.88	5.94	60.6	1.35	22.0	c.s.	u.d.	1.57
33	Durain (h.v.-B), Ill.	2.2	16.2	11.67	1.23	1.84	80.3	4.84	5.46	55.7	1.50	16.6	18	2.8	1.40
34	L.t. coke (prepared at 500°C)	1.66	8.9	2.63	1.56	0.72	89.9	3.37	8.16	83.2	1.7[b]	26.6		u.d.	1.32
35	Meta-anthracite, Newport, R.I.	0.1	32.2	3.56	0.15	0.16	95.8	0.29	8.78	89.6	1.8	330.0	c.s.	u.d.	2.33
36	Anthracite, Yunnan, China	0.6	0.2	1.39	0.71	0.47	95.6	1.57	6.50	66.3	2.2	60.5	50	1.3	1.69
37	Anthracite, Jeddo, Pa.	0.9	6.6	3.36	0.85	0.61	93.1	2.08	6.59	67.2	2.5	44.8	37	0.1	1.46
38	Subbitum.-B, Sheridan, Wyo.	14.2	6.0	15.65	1.74	0.68	77.4	4.53	4.38	44.7	3.6	17.1	15	11.1	1.27
39	H.t. coke-B, Clairton, Pa.	0.21	11.8	0.22	1.02	1.14	97.0	0.33	6.67	68.1	3.7	294.0		0.2	1.66
40	Anthracite, Nesquehoning, Pa.	2.2	9.0	2.42	0.79	0.61	94.1	1.98	5.95	60.7	3.95	47.8	20	1.3	1.46
41	H.t. coke-C, Johnstown, Pa.	0.36	13.1	2.91	0.02	1.23	95.2	0.64	6.19	63.2	4.3[b]	148.8		0.1	1.59
42	Anthracite, Plymouth, Pa.	1.0	9.1	3.56	1.0	0.97	91.9	2.57	6.53	66.6	4.4	35.7	30	u.d.	1.45
43	Anthracite, Eckley, Pa.	2.3	10.6	3.45	0.80	0.59	93.2	1.96	5.63	57.5	4.8	47.5	c.v.s.	u.d.	1.54
44	Anthracite bone, Jeddo, Pa.	2.0	18.8	3.82	0.76	0.59	93.0	2.0	5.17	52.8	5.5	46.5			1.65
45	Anthracite bone, Nesquehoning, Pa.	1.1	31.7	4.51	1.19	0.59	91.6	2.2	5.31	54.2	5.7	41.6			1.59
46	Subbitum.-C, Hanna, Wyo.	9.7	7.0	15.7	1.4	0.5	76.8	5.58	6.01	61.3	6.0	13.8	c.v.s.		1.24
47	Semi-anthracite, Limena, Peru	2.3	30.9	6.03	0.58	0.81	91.9	0.68	4.87	49.7	6.4	135.0	c.v.s.	1.0	2.20
48	Subbitum.-C, Gillette, Wyo.	21.7	6.2	20.27	0.97	0.98	72.6	5.18	2.88	29.4	10.6	14.0	0	28.2	1.23
49	Lignite, Velva, N. Dak.	17.5	8.6	19.37	1.18	0.46	75.0	3.99	2.20	22.5	16.0	18.8	0	5.7	1.21
50	Wood charcoal, E. & A. Co.	4.3	5.1	6.4	0.55	0.20	84.9	3.23	4.21	42.9	20.7	26.2		0.6	1.40
51	Lignite, Minot, N. Dak.	18.8	12.5	22.59	1.06	0.58	71.2	4.57	0.83	8.5	25.0	15.6	0	24.9	1.31
52	Lignite, Noonan, N. Dak.	25.9	8.0	20.88	1.26	0.86	72.4	4.60	1.17	11.9	69.0	15.7	0	37.6	1.32
53	Lignite, Dickinson, N. Dak.	34.6	5.7	7.01	1.26	0.70	88.4	2.63	0.75	7.7	130.0	33.6	0	14.7	1.20
54	Animal charcoal, E. & A. Co.	0.7	84.3	31.2	6.0	—	54.0	4.14	−1.73	−17.7	205.0	13.0	0	13.9	2.24

a, coal contains 5.36 pct of fossil resin.
b, flotation tests were performed in a 50-gm Denver flotation machine.
c, cling; c.s., cling slightly; c.v.s., cling very slightly.
na.f., natural floater; tr., trace.
u.d., undeterminable.

properties of surface components is valid only when a material is floated with an oily collector devoid of any reactive group[9, 11] and a frother, or with a frother only.

The surface components of coals, carbons, and hydrocarbon minerals cannot be identified directly by any known method and must be assessed from the analysis of their bulks. Obviously the analytical method is applicable only when the chemical composition of the surface and bulk of a material is roughly the same. This limitation does not necessarily reflect errors in the general principle of the hypothesis. Mathematically, the hypothesis is expressed as follows:

$$Fc = 3.5(CH'_{2.0796}) + y(C') + 0.4(S') - 4(M') - 3.4(O') - (N') - A$$

or in greater detail,

$$Fc = 3.5\left(\frac{H}{2.0796}\right) + y\left(\frac{C}{12} - \frac{H}{2.0796}\right) + 0.4\left(\frac{S}{32.06}\right) - z\left(\frac{M}{18}\right) - 3.4\left(\frac{O}{16}\right) - p\left(\frac{H}{2.0796}\right) - \left(\frac{N}{14}\right)$$

or in a condensed form,

$$Fc = x\left(\frac{H}{2.0796}\right) + y\left(\frac{C}{12} - \frac{H}{2.0796}\right) + 0.4\left(\frac{S}{32.06}\right) - z\left(\frac{M}{18}\right) - 3.4\left(\frac{O}{16}\right) - \left(\frac{N}{14}\right) \quad [2]$$

in which Fc is the calculated floatability representing the balance between the floatable and the non-floatable surface components; $CH'_{2.0796}$ is the relative number of the hydrocarbon molecules based on $C_{25} H_{52}$, which was reported by Warth[7] as the average paraffin wax from German brown coal; C' is the relative number of the excess or remnant carbon atoms, after the others have combined with hydrogen atoms to form $CH_{2.0796}$ molecules; S', O', and N' are respectively the relative number of sulphur, oxygen, and nitrogen atoms; and M' is the relative number of water molecules. These were all calculated on dry and ash-free basis, with the exception that water molecules were calculated on as-received basis. The symbols H, C, S, N, O, and M are respectively the weight percent of hydrogen, carbon, sulphur, nitrogen, oxygen, and moisture of the ultimate analysis as shown in Table I.

The assumed numerical values of factors x, p, y, and z for Eq. 2 are given in Table II. The variation of the value of factors x and p with the ash content of the tested materials is caused by the fact that ash tends to tarnish the floatable components, particularly hydrocarbons. The influence of ash, as represented first by a symbol A and then by $p(H/2.0796)$ in the derivation of Eq. 2 is taken into account by the factor x of hydrocarbon. The fact that the factor y of remnant carbon increases with a decrease of the hydrogen content of the tested materials may be explained by the work of Blayden and his associates.[12] They reported that the advancement of carbonization and/or graphitization of coals, cellulose, lignin, and glycine resulted not only in the increase of crystallinity and the crystal growth of their atoms, but also in the decrease of their hydrocarbon content. This led to the speculation that the floatability of carbon is directly proportional to the magnitude of its crystallinity. An explanation for the different values of the factor z of moisture is that the floatability of a relatively dry material is sharply lowered with the increase of certain amounts of moisture and that further increases of moisture to the already moistured material result in less depression.

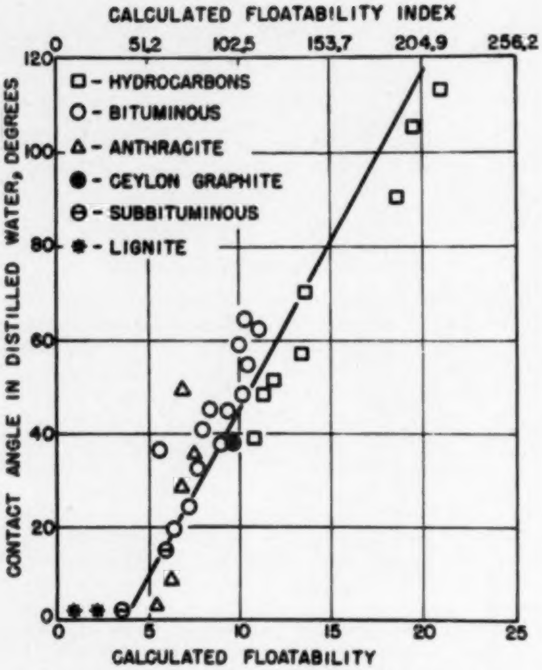

Fig. 2—Correlation between the natural floatability and the calculated floatability index of natural minerals.

Table II. The Assumed Numerical Values of Factors x, p, y, and z for Eq. 2

Ash			Remnant Carbon		Moisture	
Ash Pct, As-Received	x	p	Hydrogen Pct, Dry and Ash-Free	y	Moisture Pct, As-Received	z
0 to 8.9	3.5	0	0.08 to 0.28	1.2	0 to 14.1	4
9 to 13.0	3.0	0.5	0.29 to 1	0.8	>14.1	3
>13.0	2.5	1.0	>1	0.6		
			Porous charcoal	0.2		

The calculated floatabilities of the tested materials were converted into calculated floatability indices, using Ceylon graphite as a standard. This was done by means of Eq. 3

$$FI_c = \left(\frac{Fcm}{Fc}\right) 100 \quad [3]$$

in which FI_c is the calculated floatability index of a tested material and Fcm and Fc are, respectively, the calculated floatability of the material and the standard. By means of Eq. 2 and 3 the surface conditions and consequently the flotation properties of the tested materials can be roughly estimated. A small calculated floatability index signifies that the surface is dominated by non-floatable components and should be hydrophilic, whereas a large index denotes that the surface is dominated by floatable components and thus becomes hydrophobic.

Actual Floatability

The validity of the surface components hypothesis was checked by plotting the floatation results of the tested materials against their calculated floatability indices on a logarithmic paper and proved to be satisfactory. Fig. 1 shows that the actual floatabilities of these materials are roughly in direct proportion with their calculated indices. This relationship is mathematically expressed by Eq. 4

$$\operatorname{Log} T = k + m(FIc) \qquad [4]$$

in which T is the combined amount of petroleum light oil and pine oil, at a constant weight ratio of 1.5 to 1, in pounds per ton used for a 90 pct combustible recovery in actual flotation; k is the ordinate intercept at zero abscissa; m is the slope with minus sign; and FIc is the calculated floatability index.

The hypothesis is further supported by its capacity in explaining those flotation phenomena which contradict previous theories.[1,2] For example, according to this hypothesis, the surface of bituminous coal of medium or low volatility is more dominated by floatable components than is anthracite coal, as indicated by their calculated indices. Consequently the former should be more floatable than the latter, as found in actual flotation. The small calculated index of lignite and animal charcoal indicates that the surface of these materials is dominated by non-floatable components and should result in low floatability, as evidenced by actual flotation. The analytical data in Table I indicate that the floatable components of lignite and animal charcoal are nullified by their non-floatable components, thereby resulting in extremely small calculated indices. The remaining flotation phenomena can be similarly explained.

Natural Floatability

The premise that the floatable components are much less water-avid than the non-floatable components was verified by measuring the contact angle of materials in presence of distilled water alone. Fig. 2 shows that the calculated index required for a material to exhibit a clinging contact angle in distilled water is around 65. Beyond that the contact angle generally increases with an increase of the calculated index. This indicates clearly that the surface of naturally floatable minerals is considerably dominated by floatable components and thus becomes non-polar for air-bubble contact to occur. This type of surface occurs naturally in hydrocarbon minerals, sulphur, graphite, and some of the bituminous and anthracite coals.

Tests were also made to ascertain the effect of soaking in distilled water on the natural floatability as well as on actual floatability of some natural floaters. Curves 1 to 5 of Fig. 3 show that the air-avidity of the natural floaters tested in distilled water decreases as the soaking time is increased, owing to the adsorption of water molecules and hydroxyl ions. It is significant that a material with a relatively small index requires a much shorter soaking time in reducing its natural floatability to a negligible value than another material with a large index. Curves 2A and 2B of Fig. 3 indicate that during the preliminary soaking period the adsorbed molecules and ions are only loosely attached to the surface of natural floaters and can be easily displaced by an air bubble. The displacement gradually becomes difficult with the progress of soaking, because of the much closer association between the solid surface and water molecules. Curves 2K and 3K of Fig. 3 show that in the presence of the same amount of kerosene a natural floater with a larger index is more floatable than another natural floater with a smaller index. The same curves show also that the lowering of natural floatability by soaking in water is practically prevented by the presence of 1.4 mg per liter of kerosene. This suggests that the natural floatability of the suspended coal particles in flotation plants may be well preserved, because the mill water is usually contaminated by the oils used in mine and mill. A comparison between Figs. 3 and 4 reveals that a sharp decrease of natural floatability caused by soaking in water induces a small depression in actual flotation of materials with relatively small indices but results in no measurable depression of materials with large indices. This indicates that the adsorbed water molecules of natural floaters can be effectively displaced by oil droplets, particularly when the index of the natural floater is large.

The question of whether pure sulphur and graphite possess natural floatability has been a subject of much dispute.[3,10,14] Table III shows that pure clean sulphur and graphite exhibit measurable air-avidity in distilled water, though the organic-contaminated surface of the natural samples have higher natural floatability. The fact that previous investigators[3] failed to find a definitely measurable contact angle with pure sulphur, graphite, and bituminous coal

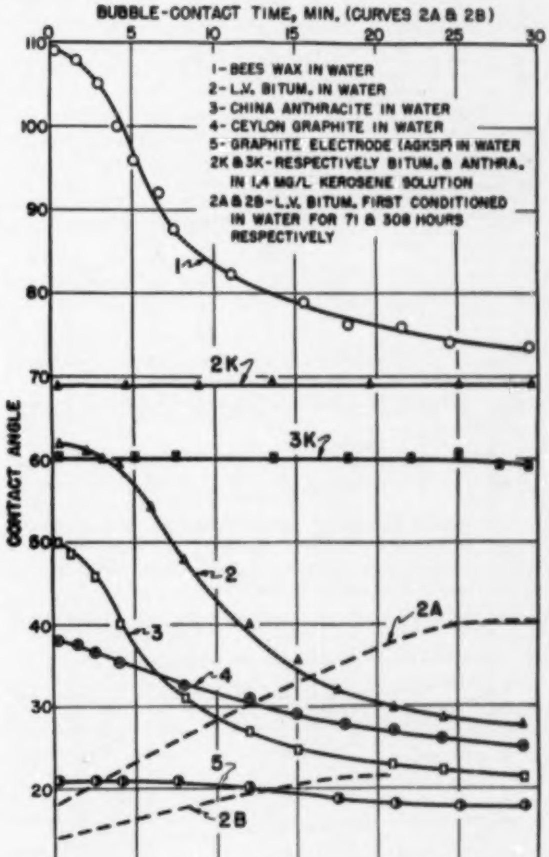

Fig. 3—Effects of soaking time and bubble-contact time on the contact angle of natural floating minerals in distilled water and kerosene solutions.

should not be interpreted as a denial of the high purity of the present samples, but rather an indication that the previous samples might be covered by a thin film of polishing powder, as suspected by Cox and Wark.[2] By adoption of the method described by Taggart and his associates,[3] the pure sulphur was prepared from a C. P. crystalline sulphur by recrystallization from thiophene-free benzene followed by nitrogen treatment. The pure graphite was made from a spectrographic electrode of AGKSP grade, furnished by the National Carbon Co., Union Carbide and Carbon Corp. The electrode was guaranteed to be 99.99+ pct pure graphitic carbon. The electrode was cut into several rectangular sticks, about 1 cm long, 0.3 cm wide, and 0.3 cm thick. These sticks were placed in the graphite tube of a graphitizing furnace,[15] and a stream of helium gas was passed constantly through the tube to prevent any reaction which would contaminate the graphite sticks or the clean graphite tube. The temperature of the tube was raised by passing a large electric current through it at reduced voltage. After the temperature reached 3100°C and remained there for 1 hr, the tube was cooled to room temperature.

Table III. The Contact Angle of Sulphurs and Graphites in Distilled Water and in Kerosene Solutions

Test No.	Material	Distilled Water: Induction Time, Min	Distilled Water: Average Contact Angle	Solution Contains 1.4 Mg Per Liter Kerosene: Induction Time, Min	Solution Contains 1.4 Mg Per Liter Kerosene: Average Contact Angle*
1	Roll sulphur	0.5	44	0.5	73
2	Roll sulphur	1.0	46	1.0	73
3	Precipitated sulphur	0.5	38	0.5	52
4	Precipitated sulphur	1.0	40	1.0	55
5	Purified sulphur	0.5	23	0.5	39
6	Purified sulphur	1.0	25	1.0	41
7	Ceylon graphite	0.5	28	0.5	52
8	Ceylon graphite	1.0	30	1.0	53
9	Spectrographic electrode AGKSP, Union Carbide & Carbon	1.0	21	1.0	32
10	Purified spectrographic electrode AGKSP	0.5	17	0.5	24
11	Purified spectrographic electrode AGKSP	1.0	18	1.0	25
12	Purified spectrographic electrode AGKSP	2.0	19	2.0	25
13	Graphite stick, Speer Carbon Co.	0.5	23	0.5	34
14	Graphite stick, Speer Carbon Co.	1.0	24	1.0	35
15	Nitrogenous graphite stick, Speer Carbon Co.	0.5	22	0.5	29
16	Nitrogenous graphite stick, Speer Carbon Co.				

* Contact angle was measured at the end of 2-min conditioning time.

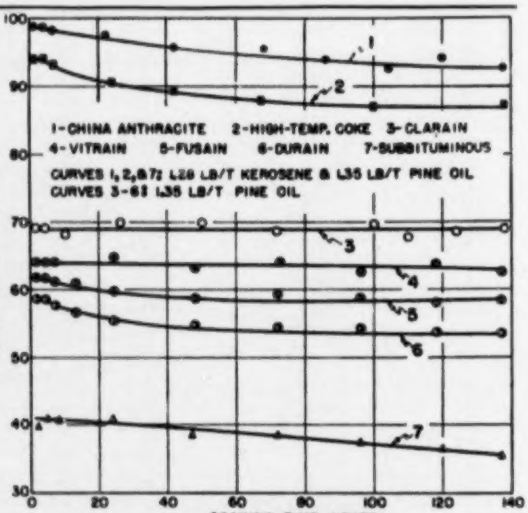

Fig. 4—Effect of soaking in distilled water on the actual flotation of various minerals.

Table IV. Relationship Among the Calculated Floatability Index, the Wettability or Hydrophobic Property, and the Adsorbability for Purified Kerosene of Minerals in Distilled Water at Room Temperature

Mineral	Approximate Amount of Purified Kerosene Adsorbed by Minerals of 48x65 Mesh, Mg Per G	Approximate Wettability of Minerals in Distilled Water: Particle Size, Mesh	Approximate Wettability of Minerals in Distilled Water: Time, Min	Calculated Floatability Index (Using Ceylon Graphite as Standard)
Wood rosin K	56.8	10x14	25.0	127.8
Low volatile bituminous	32.6	20x28	18.0	105.9
Roll sulphur	24.8	35x48	11.0	
Ceylon graphite	19.7	48x65	10.0	100.0
Clarain (h. v. bitum.)	19.5	20x28	5.0	80.8
Vitrain (h. v. bitum.)	18.6	20x28	4.0	76.4
China anthracite	17.2	28x35	3.0	66.3
Fusain (h. v. bitum.)	12.8	28x35	0.8	60.6
Durain (h. v. bitum.)	11.4	28x35	1.7	55.7
High temp. coke C.	9.3	35x48	1.1	63.2
Subbituminous C	8.0	20x28	1.5	61.3
Semianthracite	5.1	35x48	0.3	49.7
Anthracite bone	4.7	28x35	0.1	52.8
Lignite	1.4	20x28	0.9	22.5
Oxidized h. v. bitum.[a]	1.3	28x35	0.04	
Oxidized h. t. coke	1.2	35x48	0.03	
Carbonaceous slate	1.1	48x65	0.01	
Calcite	0.8	65x100	inst.	
Pyrite	0.7	48x65	inst.	
Quartz	−0.2	48x65	inst.	

[a] Oxidized with concentrated nitric acid; inst., instantaneously wetted.

Adsorption of Oils by Minerals

The premise that the floatable components are much more oil-avid than the non-floatable components was verified by testing the adsorbability of minerals for neutral oils. Table IV shows that the adsorbability of the tested minerals for purified kerosene generally increases with an increase of the calculated floatability index of the mineral. This is also true for the relationship between adsorbability and hydrophobic property, because the hydrophobic property of a mineral is roughly proportional to its calculated index. Table IV shows also that the adsorbability of coal and coke for kerosene is sharply lowered by oxidation,[8] owing to the increase of oxy-

Table V. The Adsorbability of 48x65 Mesh Ceylon Graphite for Various Liquid Hydrocarbons in Distilled Water at Room Temperature

Hydrocarbon: Name	Hydrocarbon: Solubility G/l	Amount of Hydrocarbon Adsorbed by 1 G of Graphite, Mg Per G	Number of Hydrocarbon Molecules Adsorbed by 1 G of Graphite
Benzene	0.82^{20}	0.037	2.86×10^{17}
Cyclohexane	i	0.093	6.69×10^{17}
Cyclohexene	v. sl. s.	0.462	3.41×10^{18}
Hexane	0.183^{15}	0.277	1.95×10^{18}
1 - Hexene	i	0.343	2.47×10^{18}
Decane	i	0.774	3.29×10^{18}
Undecane	i	1.280	4.96×10^{18}
Dodecane	i	6.230	2.22×10^{19}
Tridecane	i	8.091	2.66×10^{19}
Tetradecane	i	67.425	2.08×10^{20}
Hexadecane	i	91.930	2.46×10^{20}
O-thiocresol	i	50.338	2.45×10^{20}
Gasoline	sl. s.	0.470	—
Kerosene	i	16.680	—

i, insoluble; v. sl. s., very slightly soluble; sl. s., slightly soluble.

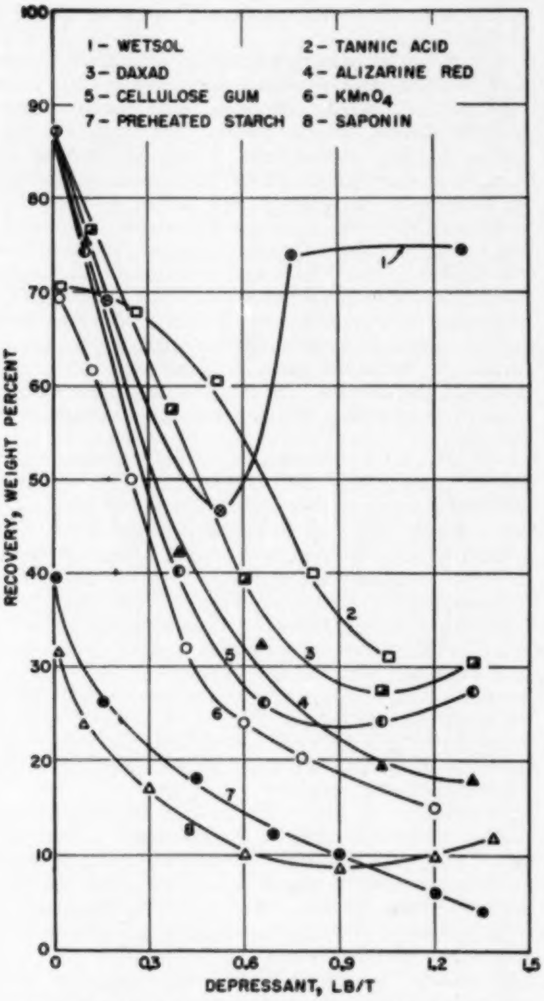

Fig. 5—Effect of various depressants on the flotation of a bituminous coal filter cake from Nemacolin, Pa. Curves 1, 3 to 5: 0.18 lb per ton Pine Oil. Curves 2 and 6: 0.14 lb per ton Pine Oil. Curve 7: 0.11 lb per ton Pine Oil. Curve 8: 0.09 lb per ton Pine Oil.

gen contents and consequently hydrophilic properties. Fig. 5 indicates that the lowering of adsorbability for oil occurs also when the surface of coal is coated with hydrophilic colloids. Table V shows that the amount of liquid paraffin hydrocarbons adsorbed by Ceylon graphite generally increases with an increase of the number of carbon atoms of the hydrocarbon. This may be caused by the fact that the hydrophobic property of these hydrocarbons, as partly indicated by solubility, gradually increases in going up the homologous series. Generally speaking, the adsorbability of minerals for neutral oils is facilitated by an increase in the hydrophobic property of the mineral and/or the neutral oil, and is inhibited or at least lowered whenever the surface of the mineral is rendered completely hydrophilic.

The above experimental data led to the postulate that oiling is a phenomenon of *hydrophobic adsorption*, because it results from mutual attraction between the hydrophobic molecules of neutral oils and the hydrophobic or floatable components of a solid surface. According to the established treatise[16] on the work of adhesion and adhesion tensions of liquids against solids, the adhesive force between an oil and a hydrophobic solid is much larger than that between the oil and a hydrophilic solid, or between water and hydrophobic solid. Although the interfacial energy of solid-liquid is not determinable by direct experimentation, the related contact angle is. The Van der Waals forces,[17] having the peculiar property of bringing like atoms together, are also expected to appear in the hydrophobic adsorption when the surface atoms of the oil and the mineral are alike. Furthermore, forces of a chemical and an ionic character cannot be ruled out entirely[18] when the oil and mineral used are not totally free of residual chemical valences, partial dipoles,[19] or polarizability.[20] Under suitable conditions, the forces involved in the adsorption of an oil by a solid are sufficient to overcome cohesive forces within the oil and thus affect a monolayer spreading of the oil over the solid surface. Yet the presence of an excessive amount of oil can create a multilayer of oiling.

An attempt was also made to ascertain the effect of crystal structure on oiling. Fig. 6 shows schematically that the molecules of alkyl hydrocarbons and the aromatic nuclei of aryl hydrocarbons can be superimposed on the molecules of solid hydrocarbons, graphite, coal, sulphur, and the sulphur layer of molybdenite. This is in line with the speculation of Van der Waarden[21] that oil molecules are adsorbed flatly upon the surface of carbon black. It would be highly tempting to regard the oiling of these solids to be largely caused by the geometrical compatibility of lattice dimensions, were it not that a superposition of oils on cellulose is also possible and that as yet no oiling seems to occur on this material. Compared with the important role played by the kind of surface components or the magnitude of hydrophobic property of the mineral and oil used, the influence exerted by the geometrical compatibil-

Fig. 6—The molecular structure of coal, graphite, hydrocarbons, sulphur, molybdenite, and cellulose.

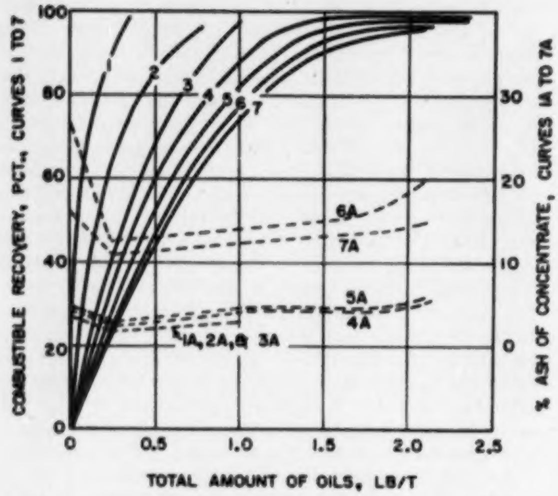

Fig. 7—Flotation of different petrographic components taken from various bituminous coals. Curves 1 and 2 are, respectively, vitrain and fusain obtained from a medium volatile bituminous coal, Springdale, Pa. Curve 3 is vitrain obtained from a high volatile—A bituminous coal, Pikeville, Ky. Curves 4 to 7 are, respectively, clarain, vitrain, fusain, and durain obtained from a high volatile-B bituminous coal, LaSalle County, Illinois.

ity between the substratum and the superstratum is of secondary importance.

The application of the surface components hypothesis in explaining the floatability of the petrographic components[od] of coals was experimentally verified. Curves 4 to 7 of Fig. 7 and tests 26 to 29 of Table I show that the floatability of petrographic components taken from a high volatile-B bituminous coal decreases in the order of clarain, vitrain, fusain, and durain, corresponding to the same order of their calculated floatability indices. This phenomenon also holds true for the petrographic components of a medium volatile bituminous coal, as shown in curves 1 and 2 of Fig. 7 and tests 18 and 19 of Table I. Furthermore, Fig. 7 and Table I show that the petrographic components of a highly floatable coal are more amenable to flotation than the corresponding petrographic components of a moderately floatable coal. For example, curves 1, 3, and 5 of Fig. 7 show that the vitrain of a medium volatile bituminous coal is more floatable than the vitrain of a high volatile-A bituminous coal, while the latter is more floatable than the vitrain of a high volatile-B bituminous coal. Table I shows that the calculated floatability index of the parent coals and that of the vitrains decrease in the same order. This is also true for fusain, as shown in curves 2 and 6 of Fig. 7.

Fig. 8 shows that the floatability of coals, carbons, and hydrocarbon minerals belonging to the same rank can be roughly correlated with their contents of fixed carbon, volatile matter, and moisture. The ash-floatability curves, not presented, showed no significant correlation. These phenomena should not be interpreted as a denial but rather as a further confirmation of the surface components hypothesis. For example, curves 1 to 6 of diagram *A* show that the floatability of coals and carbons of the same rank is directly proportional to their fixed carbon contents. This is partly attributed to the fact that the difference in hydrocarbon content between materials of the same rank is relatively small, and partly to the fact that the material of higher carbon content usually has less moisture and oxygen than another material of lower carbon content, as indicated in Table I. Conversely, curve 7 of diagram *A* shows that the floatability of hydrocarbon minerals generally decreases with the increase of fixed carbon content. This can be explained by the fact that a high content of remnant carbon atoms of these minerals is usually accompanied by a low content of hydrocarbon molecules, as revealed by actual calculations. It is rather difficult to compensate for a lowering of hydrocarbon content by increasing the carbon content, because the former is much more floatable than the latter. The carbon content of all materials, except that of lignitic coals, used in diagram *A* of Fig. 8 were calculated to dry and ash-free basis. A moist and ash-free basis was found to be more suitable for lignite.

Diagram *B* of Fig. 8 brings out two significant points. First, curves 1 to 4 show that, within the same rank, floatability of carbons and coals of subbituminous rank or higher increases as the volatile matter content decreases. This is largely because the volatile matter of these materials, being poor in hydrocarbon compounds and rich in moisture and carbon dioxide, is relatively low in floatability, and partly because, within the same rank, a high volatile coal usually contains less carbon and more moisture and oxygen than a low volatile coal, while the difference in hydrocarbon content between these two coals is relatively small. Second, in contrast to the above relationship, curves 5 and 6 of diagram B show that the floatability of hydrocarbon minerals and lignitic coals, within the same rank, generally increases as the volatile matter content increases. This is chiefly caused by the fact that the volatile matter of these materials, being rich in hydrocarbon compounds and poor in moisture and carbon dioxide, is highly floatable.

Diagram *C* of Fig. 8 shows that the floatability of

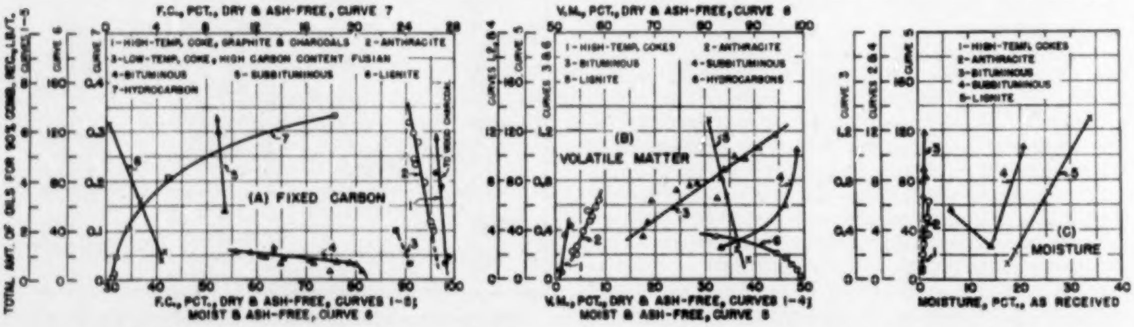

Fig. 8—Correlation between proximate components and floatability of coals, carbons, and hydrocarbon minerals.

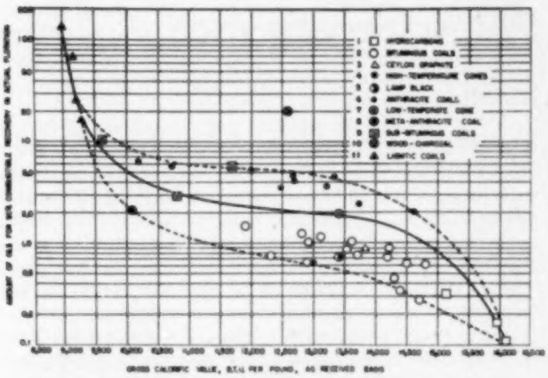

Fig. 9—Relation between the gross calorific value and the floatability of coals, cokes, and hydrocarbon minerals.

materials belonging to the same rank generally decreases with the increase of their moisture contents. The lack of any significant ash-floatability relationship is due to the fact that a large portion of the gangue minerals was liberated from coals, carbons, and hydrocarbon minerals by reduction to the —48 mesh flotation size. Thus the result of ash analysis of the flotation feed is not indicative of the amount of the interlocked gangue minerals and consequently has very little bearing on the floatability of materials tested.

Fig. 9 shows that there is a general tendency for coals, carbons, and hydrocarbon minerals of higher calorific values to have higher floatabilities. This is because the heat of combustion[22,23] of the floatable components is much larger than that of the nonfloatable components. The lack of a smooth floatability-calorific value relationship may find its explanation in the fact that the floatability and the heat of combustion of the chemical components of the tested materials are not exactly in direct proportion. This can be visualized by comparing Eq. 2 of this paper and Dulong's formula,[6e] widely used for calculating the calorific value of coal.

Summary

1—A surface components hypothesis is proposed to explain the different floatabilities of coals, carbons, and hydrocarbon minerals, floated with a neutral oil and a frother or with a frother only.

2—The actual floatability, natural floatability, and adsorbability for neutral oils of coals, carbons, and hydrocarbon minerals generally increase with the increase of their calculated floatability indices.

3—The calculated index required for a material to exhibit a clinging contact angle in distilled water alone is around 65.

4—Oiling is facilitated by an increase in the hydrophobic property of the mineral and/or the neutral oil and is inhibited whenever the surface of the mineral becomes completely hydrophilic.

5—The floatability of petrographic components not only is directly proportional to the floatability of their parent coals, but also decreases in the order of clarain, vitrain, fusain, and durain, corresponding to the same order of their calculated indices.

6—The floatability of coals, carbons, and hydrocarbon minerals belonging to the same rank can be roughly correlated with their contents of fixed carbon, volatile matter, and moisture.

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The Federal Coal Mine Safety Act

by J. J. Forbes

THE Federal Coal Mine Safety Act (Public Law 552, 82nd Congress) was approved on July 16, 1952. It incorporates, as Title I, the Coal Mine Inspection and Investigation Act of May 7, 1941 (Public Law 49, 77th Congress), which gave Federal inspectors only the right to enter coal mines for inspection and investigation purposes but no power to require compliance with their recommendations. Title II contains the enforcement provisions of the act; its purpose is to prevent major disasters in coal mines from explosions, fires, inundations, and man-trip or man-hoist accidents.

At this point a brief account of events that preceded the enactment of the Federal Coal Mine Safety Act seems appropriate. The hazardous nature of coal mining was recognized by the Federal Government as long ago as 1865, when a bill to create a Federal Mining Bureau was introduced in Congress. Little was done, however, until a series of appalling coal-mine disasters during the first decade of this century provoked a demand for Federal action. As a result an act of Congress established a Bureau of Mines in the Department of the Interior on July 1, 1910. The act made it clear that one of the foremost activities of the Bureau should be to improve health and safety in the mineral industries. One of the first projects selected by the small force of engineers and technicians then employed was to determine the causes of coal-mine explosions and the means to prevent them. By investigations after mine disasters the fundamental causes and means of prevention were soon discovered, and the coal mining industry was informed accordingly. However, despite this knowledge and the enactment of State laws and the Federal Coal Mine Inspection and Investigation Act of 1941, mine disasters continued to occur with disheartening frequency and staggering loss of life. The devastating explosion at the Orient No. 2 mine on December 21, 1951, resulted in the death of 119 men. The Orient disaster rekindled the memory of the Centralia, Ill., disaster of March 25, 1947, which caused the death of 111 coal miners. These two tragedies ultimately brought about enactment of the Federal Coal Mine Safety Act.

The act is a compromise measure. Senator Matthew M. Neely of West Virginia and Congressman Melvin Price of Illinois introduced almost identical versions in the 82nd Congress, but they were considered too drastic. The final version was introduced by Congressman Samuel K. McConnel, Jr., of Pennsylvania, after considerable discussion and amendment in committee hearings. It was passed by the Congress and became effective when signed by the President on July 16, 1952.

The act is somewhat limited in scope because it applies only to approximately 2000 coal mines in the United States and Alaska that employ regularly 15 or more individuals underground. It exempts approximately 5300 mines employing regularly fewer than 15 individuals underground and all strip mines, of which there are about 800. Moreover, it covers only conditions and practices that may lead to major disasters from explosion, fire, inundation, or man-trip or man-hoist accidents. According to Bureau records, such accidents have resulted in less than 10 pct of all the fatalities in coal mines. It is important to mention that the law is not designed to prevent the day-to-day type of accidents that have caused the remaining 90 pct or more of the fatalities, because it was the specific intention of the Congress to reserve the hazards which caused them to the jurisdiction of the coal-producing states.

Many who opposed any Federal legislation that would give the Federal inspectors authority to require compliance with mine safety regulations claimed that such legislation would usurp or infringe upon States' rights. To assure that the principle of States' rights would be preserved, the act provides for joint Federal-State inspections when a state desires to cooperate in such activities. The Director of the Bureau of Mines is required by the act to cooperate with the official mine-inspection or safety agencies of the coal-producing states. The act provides further that any state desiring to cooperate in making joint inspections may submit a State plan for carrying out the purposes of this part of the act. Certain requirements are listed; these must be met by a state before the plan can be accepted. The Director of the Bureau of Mines, however, is required to approve any State plan which complies with the specified provisions. The Director may withdraw his approval and declare such a plan inoperative if he finds that the State agency is not complying with the spirit and intent of any provision of the State plan.

When this paper was prepared, agreements for joint Federal-State inspections had been entered into with Wyoming and Washington. A few other states have indicated their desire to submit a State plan and negotiations toward that end are now under way. Reluctance to enter into such agreements may be due to the mine operators' knowledge that in the states that adopt a cooperative plan they are prohibited from applying to the Director of the Bureau of Mines for annulment or revision of an order issued by a Federal inspector and must appeal directly to the Federal Coal Mine Safety Board of Review for such action. Experience has proved that review by the Director as provided in the act is a less expensive and time-consuming procedure to all concerned than applying to the Board. Reluctance also may stem from the fact that joint Federal-State inspections somewhat restrict the movements of the State mine inspectors and tend to reduce the number of inspections of mines.

Where a State plan is not adopted, the Federal coal mine inspector is responsible under the law to take one of two courses of action if he finds certain hazardous conditions during his inspections.

The first action involves imminent danger. If a Federal inspector finds danger that a mine explosion, mine fire, mine inundation, or man-trip or man-hoist accident will occur in a mine immediately or before the imminence of such danger can be elim-

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inated, he issues a written order requiring the operator of the mine to cause all persons, except those specifically permitted by law to correct the conditions, to be withdrawn from and debarred from entering the area described in the order. The operator is not permitted under the act to resume normal operations in such an area until 1—the conditions specified in the order are corrected to the satisfaction of three duly authorized representatives of the Bureau of Mines appointed by the Director after receipt of an application from the operator for annulment or revision of such order, or 2—the Board of Review finds that after receipt of an application from the operator for annulment or revision of the order and after a formal hearing, the condition described was erroneous or no longer exists.

The second action involves one or more violations of the mine-safety provisions set forth in the act. If a Federal inspector finds that any mine-safety provision is being violated and that the violation does not cause danger that an explosion, fire, inundation, or man-trip or man-hoist accident will occur in such mine immediately or before the imminence of such danger can be eliminated, he is required to issue a written notice to the operator, giving the operator a reasonable time for correcting the violation. If upon making his check inspection to determine whether the violation has been abated in the time originally specified, the Federal inspector finds that the violation has been totally abated, he issues another written notice to that effect. If the inspector finds that the operator should be given additional time to abate the violation, he grants an extension in writing. If, however, the violation is not abated and the Federal inspector finds that circumstances, such as obvious lack of effort by the operator to correct the condition, do not justify granting an extension of time, he issues a written order requiring the operator to cause all persons, except those specifically permitted by law to correct the conditions, to be withdrawn from and debarred from entering the area described in the order. Here again the operator is prohibited from resuming normal operations in the affected area until the order is annulled or revised by the Director of the Bureau of Mines or by the Board of Review under the procedure described for imminent dangers.

It is appropriate to point out that formal applications to the Director for annulment or revision of actions taken by a Federal inspector or applications to the Board of Review must be based on orders issued by the inspectors. Neither the Director nor the Board can consider any formal action on an application to review any action of an inspector other than an order. If, however, an operator feels that he has been unjustly cited under the act for violating any mine-safety provision and if, after consultation with the inspector and the Bureau's appropriate field officials, the issues cannot be resolved, such an operator is free to present his case to the Director. Every effort will be made to resolve the differences fairly and impartially.

The act provides, of course, for judicial review by the United States Court of Appeals, and eventually the United States Supreme Court, of any final order that is issued by the Federal Coal Mine Safety Board of Review.

As has been stated, the mine-safety provisions of the act cover only those dangers inherent in coal mining that cause a relatively small percentage of the total accidents. It was clearly the intention of the Congress to cover only hazards that lead to major disasters and not to enter the field of ordinary hazards. But if the safety provisions specified in the act are complied with conscientiously by all concerned, particularly when a Federal inspector is not on the premises, major disasters will be rare.

The law provides penalties only for failure to comply with any order issued by a duly authorized representative of the Bureau of Mines. The penalties, of course, will be invoked only when all other measures to gain compliance fail. It should be pointed out, however, that the law contains no penalties for non-compliance with the mine-safety provisions between inspections of the Bureau's authorized representatives.

The act recognizes State mining laws by providing that any State or Territorial law, in effect before or after the effective date of the Federal Coal Mine Safety Act, which provides greater safety than the latter on the same phases of mining shall not be construed to conflict with the act.

When this paper was prepared the Federal Coal Mine Safety Act had been in effect for six months. Much has been accomplished during that short period. According to the records, 8007 coal mines were operated during 1952. Of these 1919 were Title II mines employing regularly 15 or more persons underground. The remainder were Title I mines, including 5281 deep mines employing regularly fewer than 15 men underground, as well as 807 strip mines.

During the six-month period after the act became effective, Bureau of Mines inspectors examined 1352 Title II mines in the United States and Alaska. They found 232, or 17 pct, free of violations of the act during their inspections. In all, 3914 violations of the mine-safety provisions were observed in the remaining 1120 mines; 1738 violations, or 44 pct, were corrected in 268 mines before the inspections were completed. Notices were not issued in instances wherein violations of the mine-safety provisions were totally abated, as determined on the spot by the inspector after inspection of the mine was completed. Except for the few instances that required issuance of withdrawal orders because of imminent danger, the operators of the other 852 mines were granted reasonable time to abate the 2176 violations, because these could not be corrected immediately. Bureau of Mines records show that about two-thirds of all the violations of the mine-safety provisions for which written notices were issued were corrected in the time originally specified. Except in a few instances requiring withdrawal orders, the inspectors granted extensions of time to correct the remaining third of the violations.

At three mines the Federal inspectors issued four withdrawal orders because of imminent danger. The imminent dangers cited were: 1—inundation, 2—likelihood of a man-trip accident owing to bad roof over haulageway (two mines), and 3—explosion. Thirteen withdrawal orders have been issued at seven mines because the violations were not abated in the time originally specified, and the inspectors decided that extensions of time were unwarranted. Twenty-one mines have been classed as gassy according to the act, primarily because the inspectors collected therein samples of mine atmospheres containing 0.25 pct or more of methane since the effective date of the act. This last statement should not be construed to mean that only 21 of the 1352 Title II mines, inspected during the first six months of operating under the act, were gassy mines. If a mine

is classed gassy by the State, before or after the effective date of the act, the operator of such mine must comply with all provisions of the Federal Coal Mine Safety Act pertaining to gassy mines; therefore, those mines that are classed gassy by State law are also classed gassy by the Federal act.

It is interesting to note that as yet not one withdrawal order has been appealed to the Federal Coal Mine Safety Board of Review. In each instance where a withdrawal order has been issued and the operator appealed to the Director of the Bureau of Mines claiming that the dangerous condition was corrected, such appeals have been acted upon promptly, regardless of whether they were received on holidays, Saturdays, Sundays, or regular working days. The Bureau is as much interested as the operators in causing no undue delay in reopening mines after violations of the law are corrected. In each instance, after prompt special investigation by three duly authorized representatives of the Bureau of Mines, the Director verified that the conditions had been corrected, the inspector's order was annulled forthwith, and the mine was permitted to resume normal operation.

Two of the 21 orders classifying mines as gassy were appealed to the Director. One appeal was denied by the Director and was carried to the Board of Review; the Board sustained the Director's decision. The other appeal was denied by the Director and was pending with the Board when this paper was completed.

The success of the Federal Coal Mine Safety Act cannot be measured by the number of violations discovered by Federal inspectors, since the act requires only one annual Federal inspection of each mine coming within its purview. The important factor is not what the mine operator does for safety when a Federal inspector is on the premises but what is done during the long periods when a Federal inspector is not there. This will be reflected in the injury rates for the mine and the entire coal-mining industry. The following information should be interesting. The calendar year 1952 was the best in the history of the American coal-mining industry with respect to the number of fatalities and the fatality rate based on million man-hours of exposure. The total number of men killed in 1952 was 546, and the fatality rate was 0.84. It is undeniable that these are 546 too many lives lost. When viewed in perspective, however, it represents considerable progress in accident prevention over the years. The figure compares favorably with 1471 coal-mine fatalities in 1942, the first full year of operation under the Coal Mine Inspection and Investigation Act of 1941, and the average of 2500 fatalities annually when the Bureau of Mines was established in 1910. Non-fatal injury rates have not improved in percentage as well as the fatal rates, but reporting of non-fatal injuries in former years was not nearly as complete as in recent years.

Present indications are that the act has increased the safety consciousness of both officials and mine workers alike. To achieve the ultimate in mine safety, all concerned must believe in it and work diligently for it. The stimulating force of a safety program must begin with top management, but to be successful it must not end there. If everyone concerned will accept his responsibility and comply with the spirit and intent of the act, the reward will be in helping to avoid the terrible waste of human values and in helping to place the coal-mining industry in a favorable safety position with respect to other important industries.

Commercial Synthesis of Star Sapphires And Star Rubies

by Clifford Frondel

THE aluminum oxide known as corundum has several varieties that have been used as gem materials since ancient times. These include the red variety called ruby, the blue variety sapphire, and the asteriated types of ruby and sapphire. Asteriated sapphire was known to the ancients under the name of *astrios*, and descriptions of this gem were given by Pliny and other early writers. The relation of these gem materials to each other as varieties of a single species, corundum, was first clearly established by Haüy in 1805 and J. M. Güthe[1] in 1809. Natural gem corundum is obtained principally in Ceylon, Siam, Burma, India, and Australia.

Star sapphires and rubies always have been highly prized and in recent years have become particularly popular in the United States. Natural star rubies of large size and fine quality are extremely rare and rank with large and fine emeralds and diamonds as the most valuable of gem stones. Interest thus attaches to the recent success in commercially synthesizing star sapphires and rubies of a size and perfection unmatched by nature.

Corundum was first synthesized as crystals in 1837 by A. Gaudin, who fused alum and aluminum oxide with potassium sulphate. Numerous other syntheses have been reported in more recent years. Summaries of this work are given in Doelter's *Handbuch der Mineralchemie*, Mellor's *Comprehensive Treatise of Inorganic Chemistry*, and other reference works. The methods employed include the reaction in the gaseous state at high temperatures of halogen compounds of aluminum with water vapor or boric oxide; the crystallization of aluminum oxide from fusion in potassium molybdate, potassium dichromate or borax; and crystallization from highly aluminous silicate melts. Red, blue, or green colored varieties can be obtained by the addition of small

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amounts of chromium, iron, or other inorganic pigmenting agents. The effective pigmenting ions in general are trivalent and comparable in ionic radius to aluminum, so that they can enter into solid solution in the crystals in substitution for aluminum. It should be emphasized that these methods of synthesis do not afford single-crystals of corundum of sufficient size or clarity to be used as gem material. In these methods it is very difficult or impossible to control the inception of crystallization, so that one or only a few crystal nuclei are formed that will then grow into relatively large individuals. It is the ease of such control that is one of the main advantages of the so-called Verneuil process of synthesizing corundum.

The first synthetic corundum of gem quality was produced commercially in about 1908 by a method developed in 1900 by a French chemist, A. Verneuil. With this method finely divided aluminum oxide is fed through an oxyhydrogen flame with a temperature of about 2000°C. The aluminum oxide usually is prepared by the thermal decomposition of carefully purified ammonium alum. The droplets of molten aluminum oxide formed in the flame are allowed to fall upon a support of fire clay or of crystalline corundum maintained at a relatively low temperature. Crystallization of the aluminum oxide then ensues and a single-crystal or an aggregate of single-crystals of corundum builds up on the support. These are referred to in the trade as boules. If a fire-clay support is employed a number of crystal nuclei may form simultaneously, giving rise to a polycrystalline boule. This undesirable result can be obviated by using a short single-crystal piece or rod of corundum as the support. Any desired orientation of the crystallographic c-axis of the corundum to the direction of elongation and growth of the boule can be effected by controlling the orientation of the rod support. The process of boule growth is a continuous one, and single-crystals of corundum weighing as much as several hundred grams may be grown. Views of boule furnaces are shown in Figs. 1 and 2. The growth of boules of suitable size and quality by this method requires careful control of the experimental conditions. Details of the Verneuil method were closely guarded by the manufacturers for many years, but adequate general accounts can be obtained in the patent literature[3] and in reference works on gem stones such as those of Bauer, *Die Edelsteinkkunde*, and Michel, *Die Künstlichen Edelsteine*.

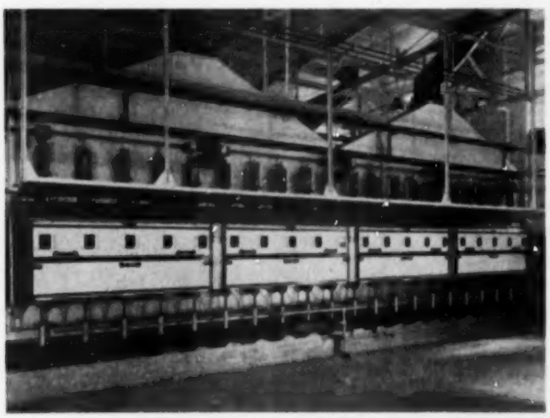


Fig. 1—Bank of boule furnaces in the Chicago plant of the Linde Air Products Co.

Fig. 2—Removing corundum boules from furnaces.

A large industry based on the Verneuil process grew up in Switzerland, France, and Germany. This has supplied yearly several thousands of pounds of synthetic corundum for use both as gem stones and as bearing materials in watches and other instruments. Since the industry was located entirely in Europe, critical shortages of synthetic corundum for technical purposes developed in the United States during World War I, and another shortage loomed at the beginning of World War II. This situation was met in 1940 by the construction of a synthetic corundum plant in the United States by the Linde Air Products Co., a subsidiary of Union Carbide and Carbon Corp. The annual U. S. production for both gem and technical purposes has been as high as 100 million carats* during the war years, but the present-day production is much less. The Verneuil process also is being used for the synthesis of single-crystals of a number of other materials valuable both for gem use and for technical purposes. These include a number of substances of the spinel-type, including gem spinel itself, $MgAl_2O_4$, together with cadmium tungstate, calcium tungstate, and ferrites, as well as rutile and other refractory oxides. Both the National Lead Co. and the Linde Air Products Co. are active in this field.

* A carat is 0.2 g.

The basic problem involved in the synthesis of star sapphires and rubies is the formation of an oriented network of acicular inclusions within the ordinary corundum boules as grown by the Verneuil method. A possible mechanism for accomplishing this is suggested by the observations of metallurgists and mineralogists on solid solutions between metals or inorganic solids. It has long been known that an originally homogeneous solid solution may become unstable and precipitate out a dissolved component, which is dispersed after precipitation in oriented fashion within the host crystal. The usual cause of the precipitation is decrease in temperature, which acts to reduce the solubility of the dissolved component, but polymorphic inversion of the host crystal, order-disorder transitions and the chemical alteration of the host crystal also are of effect in some instances.

In the case of corundum, it was found that small amounts of titanium could be introduced into solid solution in the boules. The titanium substitutes in the trivalent state for aluminum ions in the crystal structure of the corundum. If the boules are cooled

at the ordinary rate in the boule furnace in which they are grown, or are quenched in air, the titanium stays in solid solution and the boule remains transparent and homogeneous at room temperature. The solid solution is then unstable, but precipitation does not occur because of the extremely high internal viscosity of the crystal, which prevents the titanium ions from congregating and forming a separate phase. If, however, the corundum is annealed between 1100° and 1500°C in an oxidizing atmosphere for a period of time ranging upwards from a few hours, the increased thermal mobility of the titanium ions permits them to sort out. The composition of the solid solution then adjusts itself to the limiting solubility of the titanium in the corundum at the annealing temperature by the precipitation of needle-like crystals of titanium dioxide, rutile. The precipitation involves an oxidation of the titanium from the trivalent to the quadrivalent state with a concomitant diffusion of oxygen into the crystal structure. The rate of precipitation decreases with decreasing temperature and below about 1100°C is effectively nil. Precise control of the annealing conditions is important, to control the crystal size of the rutile. Over about 1500°C precipitation does not occur, and star corundum containing precipitated rutile can be homogenized by solution of the rutile by heating over about 1500°C. The titanium added to the corundum to produce the rutile ranges between about 0.06 and 0.2 atomic pct. In addition, about 1.4 pct of chromium is added as a pigmenting material to produce the red color of star rubies, and about 0.3 pct iron is added to produce the blue of star sapphires. The solubility of titanium in corundum at 2000°C appears to be limited to a maximum of a few atomic percent.

Boules containing precipitated rutile are turbid and show a sharply defined six-rayed star, equal or superior in quality to the best of the natural gems, when the boules are cut into properly oriented cabochon stones. A group of synthetic star sapphire gems is shown in Fig. 3. The rutile inclusions are clearly visible under moderate magnification and are found to be oriented in (0001) planes with their elongation parallel to the crystallographic a-axes of the corundum. A photomicrograph of the oriented, precipitated rutile inclusions in synthetic star sapphire is shown in Fig. 4. The identification of the inclusions as rutile has been proved by crushing the asteriated stones to a very small particle size in a ball mill and then separating the inclusions from the corundum by centrifuging the mixture in a heavy solution (Clerici solution), the specific gravity of which has been properly adjusted. Inclusions extracted in this way have been identified as rutile by x-ray methods together with optical and chemical tests. The asterism is due to the reflection and scattering of light by the oriented set of inclusions. Each ray of the visible star is perpendicular to a position of orientation of the inclusions. The amount of scattered light increases relative to the reflected light as the inclusions decrease in thickness to dimensions of the order of the wave-length of ordinary light. The scattering gives rise to the bluish and reddish borders that may be seen on the rays of the stars, the red side always away from the direction of incidence of the light, and to the overall reddish appearance of the star when the stone is viewed in transmitted light as compared to the bluish appearance in reflected light, the latter condition being that ordinarily obtained. The definition of the star also is influenced by the number of inclusions per unit volume, the degree of elongation and shape of the inclusions, and the orientation and perfection of polish of the cut stone. It may be noted that the precise nature of the inclusions is not of prime importance. The basic conditions that must be met to produce a star are only that the inclusions have an index of refraction different from that of the enclosing corundum, that they be elongate in shape, and that they be oriented. In some natural corundum the star or chatoyance appears to be caused by oriented sets of hollow tubules.

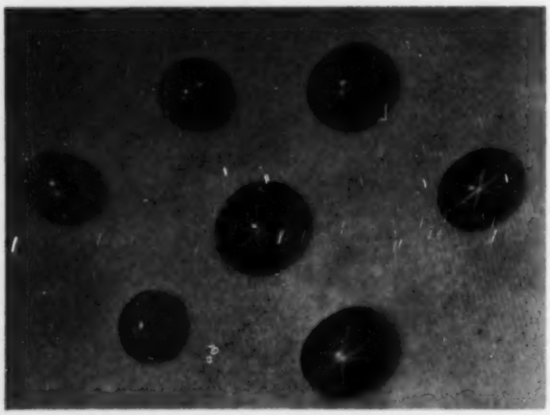


Fig. 3—Synthetic star sapphire cabochons, ranging in size from 10 to 20 carats.

Fig. 4—Photomicrograph of oriented, needle-like rutile inclusions in synthetic star sapphire. The fishhook-like crystals are twins on (011). Real magnification about X1000.

The Linde process for the synthesis of asteriated corundum was patented in 1947, and commercial production was started in the same year. Unmounted stones currently sell commercially at a retail price of about $10 to $25 a carat depending on quality. They are ordinarily available in sizes running up to about 15 or 20 carats, but much larger stones have been grown.

References

[1] J. M. Güthe: Ueber den Astrios-Edelstein, Kl. 2. Denkschr. Kön. Baierischen Akad. Wiss., Münich, 1809. 76 pp.

[2] U. S. Patents 988,230 (1911), 1,004,505 (1911) and 2,488,507 (1949); German Patent 711,293 (1941).

aime NEWS

Grayson Kirk to Speak at Welcoming Luncheon Beginning New York Annual Meeting

Dr. Grayson Kirk, president of Columbia University, will address registrants of the AIME Annual Meeting in New York February 15 to 18 at the traditional Welcoming Luncheon at 12 noon, Hotel Statler. Dr. Kirk will speak on the Bi-Centennial celebration of Columbia University.

The first social event on the program will take place on Sunday, Feb. 14, when the Mineral Industry Education Div. holds its Reception and Buffet Supper.

Registrants will have a chance to renew old friendships and trade notes early in the meeting at the cocktail party scheduled for Monday, 6:00 pm. Mining companies with headquarters in New York will be hosts for the gathering.

The Dinner-Smoker has something special this year. Dinner is scheduled to begin at 8:00 pm. Following preliminary entertainment, the Latin Quarter Show will take over the stage. Advance reports on the show say that this is one of the best ever put together by the night club—for years one of New York's most famous.

Mining, Geology, and Geophysics Div. luncheon is scheduled for Tuesday, 12:00 noon. Institute of Metals, and the Coal Div. hold their luncheons at the same time.

Branch cocktail parties and dinners, including Metals Branch, Mining Branch, and Petroleum Branch, are scheduled for Tuesday. Cocktails will be served at 6:00 pm, with dinner at 7:00 pm. The evening will be capped off with an informal dance starting at 9:00 pm and lasting until 1:00 am.

Wednesday, the early risers of the Minerals Beneficiation Div. will hold their famous Scotch Breakfast, replete with appropriate entertainment and breakfast food.

Industrial Minerals Div. and Extractive Metallurgy Div. members will meet for divisional luncheons at noon. The Annual Banquet and President's Reception start at 7:00 pm Wednesday, with the new AIME Chief Executive, Leo F. Reinartz formally taking over from current Institute President Andrew Fletcher.

At least five of the new members of the AIME Legion of Honor have signified that they will be able to attend the Banquet. The Banquet will be formal, but only those at the head table will be in white tie. Scene of the Banquet will be Park Avenue's fabulous Waldorf-Astoria, with a formal dance following dinner.

The Annual Luncheon of the Minerals Beneficiation Div. will be held Thursday at noon.

1954 ANNUAL MEETING SOCIAL FUNCTIONS

SUNDAY, FEBRUARY 14

5:30 to 7:30 P.M.	Mineral Industry Education Div. Reception and Buffet Supper

MONDAY, FEBRUARY 15

12:00 Noon	Welcoming Luncheon Dr. Grayson Kirk, president, Columbia University
6:00 P.M.	Cocktail Party (New York mining companies, hosts)
8:00 P.M.	Dinner-Smoker, Stag Dinner and entertainment provided by the Latin Quarter Show

TUESDAY, FEBRUARY 16

12:00 Noon	Mining, Geology, and Geophysics Div. Luncheon Coal Div. Luncheon Institute of Metals Luncheon

Branch Cocktail Parties and Branch Dinners

Mining Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.
Speaker, Desmond F. Kidd	
Metals Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.
Petroleum Branch	
Cocktail Party	6:00 P.M.
Dinner	7:00 P.M.

9:00 P.M. to 1 A.M.	Informal Dance

WEDNESDAY, FEBRUARY 17

8:00 A.M.	Minerals Beneficiation Div. "Scotch Breakfast"
12:00 Noon	Industrial Minerals Div. Luncheon Extractive Metallurgy Div. Luncheon
7:00 P.M.	Annual Banquet and President's Reception.

THURSDAY, FEBRUARY 18

12:00 Noon	Minerals Beneficiation Div. Annual Luncheon

Columbia U. President

Grayson Kirk will address the AIME guests at the Welcoming Luncheon on the first day of the Annual Meeting.

Coal Conference at Rolla Successful

More than 100 coal company executives and mining engineers took part in the recent two-day Coal Conference sponsored by the School of Mines and Metallurgy, University of Missouri, Rolla, Mo.

Primary purpose of the conference as outlined by J. D. Forrester, chairman of Mining Department, Missouri School of Mines . . . "is to develop and maintain interest in coal and its products so that this important industrial medium will be enhanced in all of its aspects." Mr. Forrester was in general charge of the conference and greeted registrants at the opening session.

Tom Pickett, executive vice president of the National Coal Assn., was the chief speaker at the banquet climaxing the first day's activities. In his address he called for adoption "of a sound national fuel policy" that will insure to each energy resource its "rightful share of the nation's market."

The NCA executive estimated that in 1953 coal producers spent $500 million for new equipment, maintenance, and repair of existing facilities. He said, however, that all the money spent for new equipment will have little use if Government continues to encourage competitive fuels to take coal's historic markets.

Two others who took active parts in the conference were Clayton G. Ball, vice president of the Paul Weir Co., and Harold M. Bannerman, U. S. Geological Survey. Mr. Bannerman presided at the opening session of the conference, and Mr. Ball spoke on the economic aspects of coal and the future of the coal industry.

Jackling Lecturer is Former AIME Director

Reno H. Sales, the first Daniel C. Jackling Lecturer, has been prominent in AIME activities for many years.

He was a member of the Papers and Publications Committee in 1912, 1919, and 1921. In addition he has served on Mining Geology, Engineering Education, Industrial Preparedness, and other Committees. He also was a member of the Advisory Committee to the Chicago Museum of Science and Industry.

In his role as chief geologist for Anaconda Copper Mining Co. since 1906 he has traveled in Alaska and South America. He has won several awards in recognition of his work in the geological field, including the Egleston Medal and the Penrose Medal.

The Lecture is to be given annually by a member of the mining, geology, or geophysics field who has made a significant contribution to technological progress in those areas. It is presented by the Mining, Geology, and Geophysics Div. and will be delivered each year at the Annual Meeting. Mr. Sales was chosen by a special committee for the lecture. They submitted their recommendations to the Board of Directors.

Mr. Sales was a Director of the Institute from 1923 to 1928, in addition to his other activities with the AIME.

Daniel C. Jackling, for whom the lecture is named, is one of the giants of the development of the copper industry in the U. S. He has been called "the father of the porphyries" for his pioneering of the first great porphyry copper operation. He held the AIME Presidency in 1938.

AIME members working toward making the next Pacific Northwest Conference in Portland, Oregon a success are, from left to right; Hal Seykota, Bill Wiltschko, Don W. Johnson, and Frank Cappa.

Pacific Northwest Conference

The Pacific Northwest Minerals Conference will be held April 29 to May 1, with the Oregon Section AIME as hosts. The meeting will be at the Multnomah Hotel in Portland.

The Conference started 8 years ago as a one day session under sponsorship, on an annual rotational basis, by the Oregon, North Pacific, and Columbia Sections. From a limited program dealing with industrial minerals only, sessions have expanded until now applied geology, groundwater resources, mineral industries education, extractive metallurgy, iron and steel, and physical metallurgy are included.

The Industrial Minerals Div. plans to hold three sessions. One of these will be on groundwater resources. Two others will be devoted to nine papers on the occurrence, mining, processing, transportation, and marketing of the West's nonmetallics.

Robert C. Stephenson, 1954 Chairman of the Industrial Minerals Div. will be the speaker at the Industrial Minerals Luncheon. Leslie C. Richards, Pacific Northwest Vice Chairman for Industrial Minerals is leading organization of his division's part in the technical program. Chairmen for the sessions will be Thomas M. Robins, Vernon E. Scheid, Harry W. Marsh, and George H. Waterman.

Francis X. Cappa is serving as General Chairman of the conference. Assisting Cappa in arranging the Metals program are; Harold A. Lee, G. R. Heffernan, and S. E. Maddigan. There will be four metals sessions.

1954 Annual Meeting

Mining Branch Technical Program

Feb. 15-18, 1954

Statler Hotel

New York

SUNDAY, FEBRUARY 14

Mineral Industry Education Division

2:30 pm—Faculty Club, Columbia University

CHARACTERIZATION OF THE MINERAL INDUSTRY FIELD

1. **What Qualifies a Geology Curriculum for Engineering Accreditation**
   By J. D. Forrester, Missouri School of Mines & Metallurgy
2. **Differentiating Characteristics of a Geophysical Engineer**
   By James B. Macelwane, S. J., St. Louis University
3. **Characterization of the Professional Field of Mining Engineering**
   By J. R. Van Pelt, Montana School of Mines
4. **Characterization of Fuel Technology as a Field of Mineral Industries**
   By C. C. Wright, Pennsylvania State University

7:30 pm

1. **Integration of a Metallurgical Curriculum**
   By R. Schuhmann, Jr., Massachusetts Institute of Technology
2. **On the Nature of Petroleum and Natural Gas Engineering**
   By John C. Calhoun, Jr., Pennsylvania State University
3. **Ceramics in the Mineral Industries Field**
   By V. D. Frechette, New York State College of Ceramics

WEDNESDAY, FEBRUARY 17

Mineral Economics Division

Donald H. McLaughlin and Felix E. Wormser, Associate Chairmen

Film by E. I. Dupont Co. *It Never Rains Oil*

Topic of the Session:

"A Code of Ethics of Economic Principles Pertaining to Exploration and Exploitation of Mineral Deposits."

1. **Introduction**
   By Charles W. Merrill, Assistant Chief Minerals Div., U. S. Bureau of Mines
2. **Mineral Taxation**
   By G. S. Borden, Standard Oil Co. of Calif.
3. **Major Changes in Mineral Demands**
   By Wilburn C. Schroeder, Chemical Engr., University of Maryland
4. **Discussion of Book on Mineral Economics, the three papers on this program making up three chapters of the book.**

MONDAY, FEBRUARY 15

Mining Subdivision

10:00 am

DRILLING PROBLEMS

1. **Stress Concentration Problems in Hollow Drill Steel**
   By W. H. McCormick, Chief Metallurgist, and H. J. Benecki, Metallurgist, Crucible Steel Co. of America, Park Works, Pittsburgh
2. **Manufacture of Carbide Tipped Drill Steel**
   By T. A. O'Hara, Research and Ventilation Engineer, Flin Flon, Manitoba
3. **Drilling Problems at Rhokana**
   By O. B. Bennett, M.A. Eng., (Cantab), A.R.S.M., M.I.M.M., Northern Rhodesia, Africa
4. **Drilling Practice in Swedish Mining**
   By I. Janelid, The Royal Institute of Technology, Stockholm, Sweden

2:00 pm

DRILLING PROBLEMS (cont'd)

1. **Long-Hole Drilling at the Holden Mine**
   By J. J. Curzon, Howe Sound Co., Holden, Wash.
2. **Drilling Practice at Homestake**
   By C. N. Kravig, Homestake Mining Co., Lead, S. Dak.
3. **Advances in Longhole Percussive Drilling**
   By R. G. Sullivan, Vice Pres., Minerals Engineering Co.
4. **Rotary Drilling of Rocks**
   By Tell Ertl and Robert Ryland, Ohio State University

Geology Subdivision

9:45 am

BASE METAL DEPOSITS

1. **Productive Ore Deposits of the Metaline District**
   By H. F. Mills, American Zinc, Lead & Smelting Co., Metaline Falls, Wash.
2. **General Structural Relations of the Upper Mississippi Valley Zinc-Lead District**
   By Allen V. Heyl, USGS, Beltsville, Md.
3. **The Friends Station-New Market Zinc-Bearing Area in East Tennessee**
   By C. R. L. Oder, American Zinc Co. of Tennessee, Mascot, Tenn.
4. **Structural and Stratigraphic Control of Ore Deposition in the Shasta Copper-Zinc District, Calif.**
   By A. R. Kinkel, Jr., USGS, Washington, D. C.

2:00 pm

GENERAL SESSION

Joint Session with Society of Economic Geologists

1. **Preliminary Report on Replacement and Rock Alteration in the Soudan Iron Ore Deposit, Minn.**
   By G. M. Schwartz, Geological Survey of Minnesota, Minneapolis, and Ian L. Reid, Oliver Iron Mining Div., Duluth

MONDAY, CONT'D

2. **Lateritic Nickel-Cobalt Deposits at Moa, Oriente, Cuba**
   By Richard V. Colligan, Inland Exploration Co., Havana, Cuba
3. **Hydrothermal Alteration at the Climax Molybdenite Deposit, Colo.**
   By J. W. Vanderwilt, Colorado School of Mines, and Robert U. King, USGS, Golden, Colo.
4. **Geology of the Cold Spring Tungsten Mine, Boulder City, Colo.**
   By G. C. Ridland, Consulting Geologist
5. **The Occurrence of Mineral Deposits in the Pegmatites of the Karibib-Omaruru and Orange River Areas of South West Africa**
   By E. N. Cameron, University of Wisconsin

3:00 pm

Peele Award Committee Meeting

4:00 pm

MGGD Executive Committee Meeting

Industrial Minerals Division

10:00 am

CHEMICAL RAW MATERIALS (FLUORSPAR SYMPOSIUM)

1. **Fluorspar Requirements for the United States**
   By James A. Barr, Sr., Consulting Engr., Mt. Pleasant, Tenn.
2. **Geologic Features of the Fluorspar Deposits of the United States**
   By Ralph E. Van Alstine, USGS, Washington, D. C.
3. **Fluorspar Supplies in the United States**
   By A. H. Sutton, Aluminum Co. of America, Pittsburgh
4. **Fluorspar Resources of Mexico**
   By A. H. Miller
5. **Fluorspar Resources of Europe**
   By H. R. Hose

Papers available at session:

1. **Fluorspar Deposits in Coahuila, Mexico**
   By W. P. Hewett
2. **Phosphate Rock as an Economic Source of Fluorine**
   By K. D. Jacob and W. L. Hill
3. **Newfoundland Fluorspar**
   By G. F. Carr
4. **Fluorspar Deposits of the Western United States**
   By Joseph Newton
5. **The Fluorspar Situation in Foreign Countries**
   By Louis Lipton

DIMENSION STONE AND SLATE "CLOSED" FORUM

Chairman: Charles F. Deiss

2:00 pm

CERAMICS RAW MATERIALS FILLERS, FIBRES AND PIGMENTS MINERAL AGGREGATES

1. **Recent Research Developments in High-Aluminous Refractories**
   By Kenneth Skinner
2. **Kyanite, Sillimanite and Andalusite in the United States**
   By Gilbert H. Espenshade, USGS, Washington, D. C.
3. **The Status of Block-steatite Talc Substitutes**
   By Donald R. Irving, Dept. of the Interior, Washington, D. C.
4. **Potentials for Progress in Mineral Pigments and Fillers**
   By Lincoln T. Work and S. R. Mountsier, Jr.

CEMENT, LIME AND GYPSUM

Joint Session with Minerals Beneficiation Div.

1. **Latest Practice of Burning Cement and Lime in Europe**
   By O. G. Lellep, Allis-Chalmers Mfg. Co., Milwaukee
2. **Use of Refractories in Improving Capacity and Efficiency of Rotary Kilns**
   By W. F. Rochow and W. C. Burke, Harbison-Walker Refractories Co.
3. **Suspension Preheating of Dry Pulverized Materials**
   By George K. Englehart, Fuller Co., Catasauqua, Pa.
4. **Use of Cyclones for Slurry Classification**
   By C. C. Van Zandt, Lone Star Cement Co.

Minerals Beneficiation Division

10:00 am

GENERAL BUSINESS SESSION

Chairman: Don Scott

2:00 pm

MATERIALS HANDLING

1. **Control of Fire Hazards for Conveyor Belting in Mines**
   By E. R. Traxler, Chief Dev. Engr., B. F. Goodrich Co., Akron, Ohio
2. **Application of Closed-Circuit TV to Conveyor and Mining Operations**
   By G. H. Wilson, Diamond Power Specialty Corp., Lancaster, Pa.
3. **Bin Design to Minimize Size Segregation**
   By S. D. Michaelson, Chief Engr.-Raw Materials, T.C.I. Div. of U. S. Steel Corp., Fairfield, Ala. and E. B. Nelson, General Superintendent—Coal Mines, T.C.I., Fairfield, Ala.
4. **Feeders in Beneficiation Plants**
   By O. W. Walvoord, Denver

2:00 pm

Joint Session with Industrial Minerals Div.

2:00 pm

Joint Session with Mineral Industry Education Div.

1. **Values of Advanced Management Education**
   By M. L. Mace, Prof. of Business Administration, Harvard University
2. **A Company's Appraisal of Management Development Programs Offered by Several Universities**
   By C. E. Reisle, Jr., Humble Oil and Refining Co.
3. **Management Development: How to Improve Current Effectiveness of Individual Executives**
   By Edward Walther, Management Development Associates, New York
4. **Correlation of American Mineral Engineering School Curricula and Preparation for Executive Responsibilities**
   By A. C. Dorenfeld, Assoc. Prof. of Mineral Engineering, University of Alabama

Coal Division

10:00 am

MINING METHODS IN RELATION TO RECOVERY

Joint Session with Canadian Institute of Mining and Metallurgy

Long Wall Mechanization
By Frank Doxey, Asst. General Manager, Dominion Coal Co., Montreal

2:00 pm

PREPARATION, COARSE COAL

1. **Theory and Practice of the Modern Feldspar Jig**
   By G. A. Vissac, Vancouver, B. C.
2. **Improvements in Plant and Operations**
   By J. D. Price and W. M. Bertholf, Colorado Fuel & Iron Corp.
3. **Coal Preparation at Orient Mine No. 3**
   By Howard R. Stelzriede, Franklin Coal Co., Benton, Ill.
4. **Experience Record of Equipment and Flow Changes to Improve Efficiencies and Operating Costs at a West Virginia Dense Medium Plant**
   By D. H. Dowlin, Chief Engr., Buckeye Coal Co., Nemacolin, Pa.; Edward Jolly, Preparation Engr., Youngstown Mines Corp., Dehue, W. Va.; and David R. Mitchell, Head, Dept. of Mineral Engineering, Pennsylvania State University, State College, Pa.

TUESDAY, FEBRUARY 16

Mining Subdivision

9:00 am

BLOCK CAVING

1. **Storke Level Development at Climax Molybdenum Co.**
   By E. J. Eisenach and E. Matsen, Climax, Colo.
2. **Pipeline Concrete for Mine Operations**
   By H. C. Swanson, The Cleveland-Cliffs Iron Co., Ishpeming, Mich.
3. **Use of Aluminum Forms for Concreting Mine Development Headings**
   By D. P. R. Smyth, Canadian Johns-Manville Co. Ltd., Asbestos, P. Q.
4. **Slusher Drift Development at the Jeffrey Mine**
   By H. H. Waller, Mine Supt., Asbestos, P. Q.
5. **Undercutting at the Jeffrey Mine**
   By D. L. Monroe, Canadian Johns-Manville Co., Ltd., Asbestos, P. Q.

STRATIFIED MINING

1. **Underground Haulage at the Allen Mine of the Colorado Fuel & Iron Corp.**
   By George H. Rupp, Manager, Mining Dept., Colorado Fuel & Iron Corp.
2. **Potash Mining Practice in the Carlsbad Area, N. Mex.**
   By Henry H. Bruhn and Earl H. Miller, U. S. Potash Corp.
3. **Mining Methods at the Barberton Limestone Mine**
   By H. F. Haller, Columbia-Southern Chemical Corp.
4. **Rotary Blast Hole Drilling**
   By D. T. Van Zandt, Michigan Limestone Div., U. S. Steel Corp.

12:00 Noon

MGGD LUNCHEON

E. P. Pfleider, Chairman

Presentation of Jackling Award to Reno H. Sales by Fred Searles, Jr.

2:30 pm

JACKLING LECTURE

Joint Session with Geology and Geophysics Subdiv.

1. **Jackling Lecture—Genetic Relations Between Granites, Porphyries and Associated Copper Deposits**
   By Reno Sales, Consulting Geologist, Anaconda Copper Mining Co.
2. **A Successful Exploration Project, the Geophysical Discovery and Development of the Pima Mine, Pima County, Arizona**
   By W. E. Heinrichs, Jr., R. E. Thurmond, and E. D. Spaulding, Pima Mining Co., Tucson, Ariz.
3. **Cylindrical Color Photography of Bore Holes**
   By E. B. Burwell, Jr. and R. H. Nesbitt, Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

Geology Subdivision

9:00 am

Joint Session with Society of Economic Geologists and Industrial Minerals Div.

RADIOACTIVE MATERIALS

1. **Investigations of Uranium-Bearing Deposits of the Boulder Batholith, Mont.**
   By E. E. Thurlow, Salt Lake City, Utah and Leonard D. Jarrad, U. S. Atomic Energy Comm., Butte, Mont.
2. **Progress Report on the Origin of Uranium Deposits**
   By D. L. Everhart, U. S. Atomic Energy Comm.
3. **Edith River Uranium Deposits**
   By N. H. Fisher, Bureau of Mineral Resources, Canberra, Australia
4. **Uranium Exploration, Rum Jungle Province, Australia**
   By C. J. Sullivan and N. H. Fisher, Bureau of Mineral Resources, Canberra, Australia
5. **Development of Monazite Exploration Techniques**
   By Robert F. Griffith

2:30 pm

Joint Session with Mining and Geophysics Subdiv.

Geophysics Subdivision

9:00 am

1. **Depth Determinations by Electrical Resistivity**
   By Harold Mooney, Dept. of Geophysics, University of Minnesota, Minneapolis
2. **Construction of the Gish-Rooney Commutator**
   By Shelley Krasnow, President, Georator Corp., Manassas, Va.
3. **Geophysical Case History of a Commercial Gravel Deposit**
   By Rollyn P. Jacobson, Washington University
4. **Theory of Exploration by Induced Polarization and Its Decay**
   By David F. Coolbaugh, Golden, Colo.

2:30 pm

Joint Session with Mining and Geology Subdiv.

Industrial Minerals Division

9:00 am

CAREERS IN INDUSTRIAL MINERALS

1. **Introductory statement**
2. **Training for a Career in Industrial Minerals**
   By R. B. Ladoo, Boston
3. **Mining Engineering in the Portland Cement Industry**
   By F. T. Agthe, Allis-Chalmers Mfg. Co., Milwaukee
4. **Experience in the Introduction of Talc as a Ceramic Material**
   By Henry Mulryan
5. **Careers Related to Industrial Waters**
   By Jack W. Graham

RARE MINERALS I

Joint Session with Society of Economic Geologists and Geology Subdiv.

TUESDAY, CONT'D

2:00 pm

RARE MINERALS II

1. **Monazite Dredging and Concentration in Idaho**
   By J. Hall Carpenter and Robert V. Spencer, Jacksonville, Fla.
2. **Chemical and Mineralogical Characteristics of Titaniferous Concentrates from North Carolina; Quilon, Brazil; and Florida Beach Sands**
   By L. E. Lynd, H. Sigurdson, C. H. North and W. W. Anderson, National Lead Co.
3. **Columbium-bearing Rutile Deposits in the U. S.**
   By E. P. Keiser, USGS, Denver
4. **Lithium Resources of South America**
   By W. B. Mather, Southwest Research Institute
5. **Selenium as a Strategic Metal**
   By J. D. Sargent, U. S. Bureau of Mines, Washington, D. C.

Minerals Beneficiation Division

8:00 am

MBD SCOTCH BREAKFAST

9:00 am

CRUSHING AND GRINDING COMMITTEE

1. **Free Radicals and Chemical Reaction in Comminution**
   By A. M. Gaudin, Prof., Mineral Dressing, Massachusetts Institute of Technology
2. **Analysis of Variables in Rod Milling**
   By Will Mitchell, Jr., Asst. Dir. of Research, Allis-Chalmers Mfg. Co., Milwaukee
3. **Spiral Lifters in Ball Mills**
   By E. J. Klovers, Engr., Allis-Chalmers Mfg. Co., Milwaukee
4. **Screen Sizing Sub-Micron Particles**
   By R. J. Charles, Massachusetts Institute of Technology

OPERATING CONTROL

1. **A Quick Estimation of Mill Product Purity by Transparency Measurements**
   By S. C. Sun, Assoc. Prof. of Mineral Preparation, Pennsylvania State University, State College, Pa.; H. M. Fisher, Tech. Supervisor of Natrona Plant, Pennsylvania Salt Mfg. Co., Natrona, Pa.; R. E. Snow, Graduate Student, Pennsylvania State University, State College, Pa.
2. **Factors Affecting the Accuracy of Conveyor Scales**
   By R. O. Bradley, Dir. of Engr., Toledo Scale Co., Toledo, Ohio
3. **Inertial Flowmeters for Mass Flow Measurement**
   By W. A. Jones, President, Control Engineering Corp., Norwood, Mass.
4. **Servo-Technique in Process Control**
   By N. H. Dorenfeld, Southwestern Engineering Co., Los Angeles

2:00 pm

SOLUTION AND PRECIPITATION

Joint Session with Extractive Metallurgy Div.

1. **Electrolytic Production of Hydrometallurgical Reagents for Processing Manganese Ores**
   By J. B. Clemmer, Carl Rampacek and P. E. Churchward, U. S. Bureau of Mines
2. **Operations of the Sherritt Gordon Pilot Plant**
   By F. A. Forward and V. N. Mackiw, University of British Columbia, Vancouver, B. C.
3. **Specific Data on Ion-Exchange in the Metallurgical Industry**
   By A. B. Mindler, Permutit Co., New York
4. **Continuous Ion-Exchange in Metallurgy**
   By E. A. Swinton, R. McNeil, and D. E. Weiss, Commonwealth Scientific Industrial Research Organization, Melbourne, Australia
5. **A Practical Determination of Residence Time and Short Circuiting of Dry Solids or Solids in Slurries in Continuous Systems**
   By R. B. Coleman and J. D. Moore, Vitro Chemical Co., Salt Lake City

CONCENTRATION

1. **Flotation Characteristics of Pyrrhotite with Xanthates**
   By C. S. Chang, S. R. B. Cooke and I. Iwasaki of University of Minnesota
2. **Mineral Flotation with Ultrasonically Emulsified Reagents**
   By S. C. Sun, Assoc. Prof. of Mineral Preparation, Pennsylvania State University, State College, Pa., and L. Y. Tu and E. Ackerman
3. **Starches and Starch Products in Amine Flotation of Iron Ore**
   By C. S. Chang, S. R. B. Cooke and R. Huch of University of Minnesota
4. **Laboratory & Industrial Flotation of Oxidized Zinc Ores with Fatty Amines**
   By Maurice Ray, Director of Research, School of Mines & Metallurgy, Paris, and P. Raffinot
5. **Flotation Theory: Molecular Interactions between Frothers and Collectors at Solid-Liquid-Air Interfaces**
   By J. Leja, Dept. of Colloid Science, University, Cambridge, England, and J. H. Schulman

Coal Division

9:00 am

PREPARATION, FINE COAL

Joint Session with Canadian Institute of Mining and Metallurgy

1. **Evaluation of the Performance of a Cleaning Unit**
   By J. Visman, Preparation Engr., Mines Branch, Calgary, Alberta
2. **Factors in the Design and Operation of Launder Screens**
   By W. S. Sanner and J. D. Clendenin, U. S. Bureau of Mines, Schuylkill Haven, Pa.
3. **D. S. M. Cyclone Washers in Coal Preparation**
   By F. J. Fontein, Research Engr., and C. Krijgsman, Head, Coal Preparation Div., Dutch State Mines, Limburg, Netherlands
4. **Wetting Agents in the Flotation of Coal**
   By Shiou-Chuan Sun, Assoc. Prof. of Mineral Preparation, and Delaskar Giraldo-Galvez, Pennsylvania State University, School of Mineral Industries, State College, Pa.

12:00 Noon

COAL DIV. LUNCHEON

2:00 pm

MINING METHODS

1. **Induced Caving of Anthracite Beds**
   By Andrew Allan, Jr., Mining Engr., U. S. Bureau of Mines, Schuylkill Haven, Pa. and Russell S. Davies, Newkirk Colliery, Tamaqua, Pa.
2. **Mining of Pitching Seams in Canadian Cordillera**
   By H. Wilton-Clark, Coleman Collieries Ltd., Coleman, Alberta
3. **The Economic and Psychological Factors in Successfully Mining Coal Under Heavy Water-Bearing Strata**
   By James D. Reilly, Vice President, Hanna Coal Co., St. Clairsville, Ohio

6:00 pm

MINING BRANCH COCKTAIL PARTY

7:00 pm

MINING BRANCH DINNER

WEDNESDAY, FEBRUARY 17

Mining Subdivision

9:00 am

The Greater Butte Project—Design and Operations
Part 1—Plant Design and Construction
Part 2—Slime Filling Operations
Part 3—Shaft Sinking and Raising
Part 4—Development and Mining Operations
Part 5—Applied Mining Research
By A. R. Sims, H. M. Stroock, Edward Bonner, M. K. Hannifan, Al Rood, Marcus McAnna, Frank Ralph, L. F. Bishop, and R. L. Sandvig.

2:00 pm

UNDERGROUND MINING PROBLEMS

1. **White Pine Mining Operations**
   By R. F. Moe, White Pine Copper Co., Star Route, Ontonagon County, Mich.
2. **The Ivanhoe Shaft Sinking**
   By K. R. Winslow, Austinville, Va.
3. **Chrome Mining in Southern Rhodesia**
   By Parke A. Hodges, Behre Dolbear & Co., New York
4. **Uranium Prospecting and Mining**
   By Philip N. Simmons, Grand Junction, Colo.

Geology Subdivision

9:00 am

Joint Session with Geophysics Subdiv.

1. **Geophysical Prospecting in New Brunswick**
   By S. H. Ward, c/o McPhar Geophysics Ltd., Toronto, and H. O. Seigel, Geophysical Consultant, Toronto.
2. **Comparison of Geochemical, Geological, and Geophysical Prospecting Methods at the Malachite Mine, Jefferson County, Colo.**
   By Lyman C. Huff, USGS, Denver
3. **An Electromagnetic Method for Use in Deep Drill Holes**
   By S. H. Ward, Toronto
4. **Importance of Low Level Recording in Airborne Magnetic Surveys**
   By Hans Lundberg, President, Lundberg Explorations Ltd., Toronto
5. **The Earth Sciences Program of the National Science Foundation**
   By H. Kirk Stephenson, National Science Foundation, Washington, D. C.

2:00 pm

PORPHYRY COPPER DEPOSITS

1. **Certain Structural Features of Porphyry Copper Deposits in the Western and Southwestern United States**
   By E. N. Pennebaker, Scottsdale, Ariz.
2. **Structural Control of Globe-Miami District, Ariz.**
   By N. P. Peterson, Globe, Ariz.
3. **Structure and Mineralization, Silver Bell, Ariz.**
   By K. V. Richard and J. H. Courtright
4. **Geologic Structure Around the Santa Rita, N. Mex., Intrusive**
   By Georges Ordonez and W. W. Baltosser

Geophysics Subdivision

9:00 am

Joint Session with Geology Subdiv.

2:00 pm

1. **Use of Seismograph to Determine Lateral Stratigraphic Variations for Mining Investigations**
   By R. M. Tripp, Research Inc., Dallas, and Thomas R. Shugart, Texana Exploration, Dallas
2. **Direct Oil Finding Techniques**
   By Leo Horvitz, Houston
3. **Discovery of Disseminated Lead-Zinc Ores By Gravimeter Prospecting**
   By Albert J. Frank
4. **Near Surface Velocity Problems—Williston Basin**
   By Richard H. Hopkins, Sun Oil Co.
5. **Shallow Depth Seismic Refraction Exploration**
   By R. Burton Rose, San Jose, Calif.
6. **The Effects of Geologic Features on Radio Wave Transmission**
   By William Pulley

Industrial Minerals Division

9:00 am

SPECIAL SANDS AND ABRASIVES I

1. **Emery, Its Nature and Occurrence**
   By Gerald M. Friedman, University of Cincinnati
2. **High-purity Silica Resources of Northeastern United States**
   By Thomas D. Murphy, USGS, Washington, D. C.
3. **Crushing, Treating and Sizing of Abrasives**
   By H. L. Schultz, Niagara Falls, N. Y.
4. **Natural Abrasives**
   By T. H. Janes, Engineer, Industrial Minerals Division, Dept. of Mines and Technical Surveys

12:00 Noon

INDUSTRIAL MINERALS DIV. LUNCHEON

Toastmaster: H. N. Bannerman

2:00 pm

SPECIAL SANDS AND ABRASIVES II

1. **Greater Economy in the use of Industrial Diamonds by Proper Bonding Methods**
   By Henry Schwarzkopf, Consolidated Diamond Tool Corp., Yonkers, N. Y.
2. **Natural Abrasive Sands of the Ottawa, Ill., District**
   By W. B. Guyer
3. **The Hydro-classification of Fine Abrasives**
   By Louis F. Rowe, American Optical Co.
4. **Quality Testing of Abrasives**
   By F. Paul Ronca, Carborundum Co.

4:30 pm

Industrial Minerals Div. Executive Committee Meeting

Minerals Beneficiation Division

9:00 am

CONCENTRATION

1. **Milling Kentucky Fluorspar Tailings**
   By LaMont West and R. R. Walden, Pennsylvania Salt Mfg. Co., Calvert City, Ky.
2. **The Beneficiation of Cassiterite**
   By R. C. Meaders, Aerofall Mill Co.
3. **Progress in Flotation of Cassiterite**
   By T. F. Mitchell, U. S. Bureau of Mines, Salt Lake City
4. **Manganese Upgrading at Three Kids**
   By S. J. Carroll, Manganese Inc., Henderson, Nev.
5. **Comparison of Ferrosilicon Recovery**
   By G. A. Komadina, Eagle-Picher Co., Cardin, Okla.

WEDNESDAY, CONT'D

9:00 am

SOLIDS-FLUIDS SEPARATION

1. **Collection of Fumes from Ferro-silicon Electric Furnace Operations**
   By Leslie Silverman, Harvard University and R. A. Davidson, Vanadium Corp. of America
2. **The Collection of Laboratory Dusts**
   By B. Langston and F. Stephens, Battelle Memorial Institute, Columbus, Ohio
3. **A Practical Approach to Selection of Filter Media**
   By Frank Weems, Eimco Corp., New York
4. **Design and Operating Results of the Eimco Horizontal Pan Filter**
   By R. C. Emmett and D. A. Dalstrom, Eimco Corp., Chicago
5. **The Drying of Lateritic Ores**
   By B. Marquis, H. Reed, and E. R. Sweet, Singmaster & Bryer Co., New York

2:00 pm

PYROLYSIS AND AGGLOMERATION

1. **Sinter is What You Make It**
   By E. H. Rose, Research Engineer, and D. J. Reed, T. C. I. Div., U. S. Steel Corp., Fairfield, Ala.
2. **Looking at Sinter Testing**
   By E. H. Kinelski, Fellow, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh, and H. A. Morrissey and R. E. Powers
3. **Solid State Bonding in Iron Ore Pellets**
   By S. R. B. Cooke, School of Mines & Metallurgy, University of Minnesota, Minneapolis
4. **FluoSolids Roasting of Pyrite Telluride Flotation Concentrates at Golden Cycle Corporation's Carlton Mill**
   By H. R. Keil, Mill Supt., Carlton Mill, Golden Cycle Corp., Cripple Creek, Colo.
5. **FluoSolids Conversion of Iron Ores to Magnetites**
   By R. J. Priestley, The Dorr Co., Stamford, Conn.

Coal Division

9:00 am

CONTINUOUS MINING

1. **Ventilation and Dust Control for Continuous Mining**
   By J. E. Elkin, General Superintendent, Coal Dept., Duquesne Light Co., Pittsburgh
2. **Remote Control for Continuous Mining**
   By Arthur L. Lee, Owner and Chief Engineer, A. L. Lee & Co., Columbus, Ohio
3. **Pillar Extraction in the Pittsburgh Bed with Continuous Miners**
   By W. E. Hess, Gen. Supt., Vesta-Shannopin Coal Div., Jones & Laughlin Steel Corp.

2:00 pm

AIR AND WATER POLLUTION

Symposium on Control of Gob Pile Fires
By Harry F. Hebley, Research Consultant, Pittsburgh Consolidation Coal Co., Pittsburgh, William L. Nelson and Ernest P. Hall, Mellon Institute, Pittsburgh, George H. Kennedy, Preparation Engr., Rochester & Pittsburgh Coal Co., Indiana, Pa., Thomas G. Ferguson, Vice President, Pittsburgh Coal Co., Library, Pa., and J. A. Younkins, Asst. General Supt., Coal Dept., Duquesne Light Co., Pittsburgh

STRIP MINING

1. **Long Distance Overland Haulage by Conveyor**
   By J. L. Thornton, Manager, Coal Div., Belting Sales Dept., Goodyear Tire & Rubber Co.
2. **Lignite Stripping**
   By W. B. Roe, Geologist, Truax-Traer Coal Co.
3. **Blast Hole Drilling**
   By Jason Harmon, General Supt., Strip Operations and J. D. Reilly, Vice President, Hanna Coal Co., St. Clairsville, Ohio

12:00 Noon

MINERAL INDUSTRY EDUCATION DIVISION LUNCHEON

THURSDAY, FEBRUARY 18

Mining Subdivision

9:00 am

SUPPORT OF MINE WORKINGS

1. **The Use of Fill at the Franklin Mine**
   By C. M. Haight, New Jersey Zinc Co., Franklin, N. J.
2. **Applications of Rock Bolting**
   By Edward M. Thomas, Chief, Roof Control Section, U. S. Bureau of Mines, Washington, D. C.
3. **Analysis of Roof Bolting Systems Based on Model Studies**
   By Louis A. Panek, U. S. Bureau of Mines, College Park, Md.
4. **Western Rock Bolting Practice**
   By Lloyd Pollish, Anaconda Copper Mining Co., Butte, Mont., and Robert Breckenridge, Sunshine Mining Co., Kellogg, Idaho

9:00 am

INDUSTRIAL WATERS I

Joint Session with Geology and Geophysics Subdiv. and Industrial Minerals Div.

1. **Introduction**
   By Richard M. Foose
2. **Development and Construction of a Ground Water Supply**
   By Owen F. Jensen, Jr., Consulting Ground-Water Geologist, Houston, Texas
3. **The Importance of Ground Water to the Future of Arizona's Mining Industry, and the Relation of Industrial Water Supplies to Irrigation Supplies and the Legal Control Thereof**
   By Elmer D. Hershey, Exec. Secretary, Arizona Underground Water Commission, Phoenix, Ariz.
4. **Water Supply from Dual Source for Industrial Plant**
   By R. D. Wilson, Consulting Engr., Champaign, Ill.
5. **Mine Drainage Problems, Anthracite Region of Pennsylvania**
   By S. H. Ash, Chief, Safety Branch, U. S. Bureau of Mines, Silver Spring, Md.

2:00 pm

INDUSTRIAL WATERS II

Joint Session with Geology and Geophysics Subdiv. and Industrial Minerals Div.

1. **Appraising Water Conditions of the Cayia Mine**
   By Peter P. Ribotto, Inland Steel Co., Ishpeming, Mich.
2. **Mining-hydrology Problems in the Birmingham Red Iron Ore District**
   By Thomas A. Simpson, USGS, University, Ala.
3. **Pumping Test Evaluates Water Problem at Eureka, Nev.**
   By Wilbur T. Stuart, Ishpeming, Mich.
4. **Determination and Elimination of Recirculation of Surface Water at Jefferson City, Tennessee**
   By Raymond M. Richardson, Geologist, USGS. Knoxville, Tenn.

5. **Ground Water Control in Underground Mining**
By R. C. Mahon, Supt., Homer Mine, M. A. Hanna Co., Iron River, Mich.

Geology Subdivision

9:00 am

Joint Session with Mining and Geophysics Subdiv. and Industrial Minerals Div.

2:00 pm

Joint Session with Geophysics and Mining Subdiv. and Industrial Minerals Div.

Geophysics Subdivision

9:00 am

Joint Session with Mining and Geology Subdiv. and Industrial Minerals Div.

2:00 pm

Joint Session with Mining and Geology Subdiv. and Industrial Minerals Div.

Industrial Minerals Division

9:00 am

Joint Session with Mining, Geology, and Geophysics Subdiv.

2:00 pm

Joint Session with Mining, Geology, and Geophysics Subdiv.

Minerals Beneficiation Division

9:00 am

MBD SYMPOSIUM

WHAT'S NEW IN MILLING

A series of short papers on latest developments in the field of minerals beneficiation—equipment and methods

12:00 Noon

MBD LUNCHEON

Don Scott, Master of the Situation

2:00 pm

CLEAN-UP SESSION

Coal Division

9:00 am

UTILIZATION

1. **Non-Fuel Uses of Anthracite Coal**
By Raymond C. Johnson, Vice President, Research, Anthracite Institute, Wilkes-Barre, Pa.
2. **Non-Fuel Uses of Bituminous Coal**
By Harold J. Rose, Bituminous Coal Research Inc., Pittsburgh
3. **A Short University Course for Technical Training of Coal Salesmen**
By W. W. Bayfield, Exec. Vice President, American Coal Sales Assn., Washington, D. C.

2:00 pm

UTILIZATION

1. **Underground Electro Carbonization**
By James D. Forrester, Chairman, University of Missouri, School of Mines and Metallurgy, Rolla, Mo., T. C. Cheasley, Asst. to President, and Erich Sarapuu, Research Consultant, St. Clairsville Coal Co., Kansas City, Mo.
2. **Distribution of United States Coal Reserves**
By Paul Averitt, USGS, Washington, D. C.

Extractive Metallurgy Division

MONDAY, FEBRUARY 15

9:45 am

ALUMINUM

1. **Production of Aluminum-Silicon Alloys from Smelting of Clays and Other Aluminum Silicates**
By W. F. Hergert and L. H. Banning, U. S. Bureau of Mines, Albany, Ore.
2. **Operation of Experimental Plant for Recovery of Alumina from Anorthosite**
By H. W. St. Clair, U. S. Bureau of Mines, Laramie, Wyo.

9:45 am

SYMPOSIUM ON ARC-FURNACE COPPER MELTING

1. **Electric Furnace Melting Practice at Canadian Copper Refiners, Ltd.**
By W. Sheaffer, Canadian Copper Refiners Ltd., Montreal
2. **Round Table Discussion**

2:00 pm

ALUMINUM

1. **Cost Factors in Utilization of Foreign Bauxite**
By A. F. Johnson, Consult., Alton, Ill.
2. **General Prospects and Technology of Using Processed Low-rank Fuels for Electric Power**
By V. F. Parry, U. S. Bureau of Mines, Denver
3. **The Direct Reading Spectrograph in Aluminum Smelting**
By D. L. Colwell and O. Tichy, Apex Smelting Co., Cleveland
4. **Effect of Phosphate in Alumina on the Current Efficiency During Electrolysis of Aluminum**
By A. C. Byrns, Kaiser Chemical Co., Oakland, Calif.

2:00 pm

SYMPOSIUM ON ARC-FURNACE COPPER MELTING (Cont'd)

TUESDAY, FEBRUARY 16

7:30 am

EXECUTIVE COMMITTEE BREAKFAST

R. R. McNaughton, Chairman

9:00 am

LEAD-ZINC

1. **The Desilverizing of Lead Bullion**
By R. Davey, The Broken Hill Associated Smelters Pty. Ltd., Port Pirie, S. Australia
2. **Thoughts on Lead Blast-Furnace Practice**
By L. B. Haney and R. J. Hopkins, The Broken Hill Associated Smelters Pty. Ltd., Port Pirie, S. Australia
3. **Operation of the Midvale Dwight-Lloyd Sintering Plant and Lead Blast-Furnaces on a Two-Shift Basis**
By H. L. Johnson and C. A. Nelson, Midvale Plant, U. S. Smelting Refining and Mining Co., Salt Lake City

9:00 am

HYDROMETALLURGY-PHYSICAL CHEMISTRY

1. **Kinetics of the Oxidation of Galena in Ammonium Acetate Solution Under Oxygen Pressure**

By D. P. Seraphim, C. S. Sames, University of British Columbia, Vancouver, B. C.

2. **Treatment of Uranium Ores by Basic Pressure Leaching Methods**
   By J. Halpern and F. A. Forward, University of British Columbia, Vancouver, B. C.
3. **Fundamentals of Agitation and Applications to Extractive Metallurgy**
   By J. H. Rushton, Illinois Institute of Technology
4. **Some Factors Affecting the Structure of Zinc Electrodeposits**
   By J. H. Nicholson, G. H. Turner, and J. A. Brown, Consolidated Mining and Smelting Co. of Canada, Trail, B. C.

2:00 pm

LEAD-ZINC-CADMIUM

1. **Additional Information Regarding the Conditioning of Vapors from Electrothermic Zinc Furnaces**
   By F. A. Poland, Revere Copper and Brass Inc.
2. **Roasting Metallic Sulphides in a Fluid Column:**
   Part I — Experimental Development: H. M. Cyr, C. W. Siller, and T. F. Steele, New Jersey Zinc Co., Palmerton, Pa. Part II — Commercial Development: A. J. Myhren, C. W. Siller, and S. I. Hammond, New Jersey Zinc Co., Palmerton, Pa.
3. **Fluidity of Some Lead Blast-Furnace Slags**
   By T. D. de Souza Santos, Inst. de Pesquisas Tech., Sao Paulo, Brazil
4. **An Important Byproduct of Zinc Recovery—Cadmium in Review**
   By J. R. Musgrave and A. P. Thompson, Eagle-Picher Co., Joplin, Mo.
5. **A Practical Determination of Residence Time and Short Circuiting of Dry Solids or Solids in Slurries in Continuous Systems**
   By R. B. Coleman and J. D. Moore, Vitro Chemical Co., Salt Lake City

2:00 pm

SOLUTION AND PRECIPITATION

Joint Session with Minerals Beneficiation Div.

(See page 86)

WEDNESDAY, FEBRUARY 17

9:00 am

PHYSICAL CHEMISTRY OF EXTRACTIVE METALLURGY

Joint Session with IMD

1. **Improved Vacuum-Fusion Method for the Determination of Oxygen and Nitrogen in Metals**
   By N. A. Gokcen, Michigan College of Mining and Technology, Houghton, Mich.
2. **Theoretical Analysis of Diffusion of Solutes During the Solidification of Alloys**
   By C. Wagner, Massachusetts Institute of Technology, Cambridge, Mass.
3. **The Vapor Pressure of Zinc Sulphide from 680° to 825°C**
   By G. L. McCabe, Carnegie Institute of Technology
4. **Determination of the Standard Free Energy of Formation of Zinc Sulphide and Magnesium Sulphide**
   By W. Curlook and L. M. Pidgeon, University of Toronto, Toronto

9:00 am

TITANIUM

1. **Inherent Problems in the Extractive Metallurgy of Titanium by Chloride Processes**
   By W. R. Opie, National Lead Co., South Amboy, N. J.
2. **Smelting of Titaniferous Ores**
   By D. L. Armant, National Lead Co., South Amboy, N. J.
3. **Commercial Titanium Metal Production**
   By P. J. Maddex, Titanium Metal Corp., Henderson, Nev.
4. **Production and Purification of Titanium Tetrachloride**
   By L. W. Rowe, National Lead Co., South Amboy, N. J.

2:00 pm

PHYSICAL CHEMISTRY OF EXTRACTIVE METALLURGY (Cont'd)

1. **System Ag_2O-B_2O_3: Its Thermodynamic Properties as a Slag Model**
   By G. M. Willis, University of Melbourne, Melbourne, Australia, and F. L. Hennessy, Mt. Morgan Ltd., Mt. Morgan, Queensland, Australia
2. **Liquid System NaCl-$ZrCl_4$: Vapor Pressure and Liquidus**
   By L. Howell, J. T. Benedict, H. H. Kellogg, Columbia University
3. **Exchange of Antimony Between Molten Antimony and Fused Antimony Oxide**
   By D. Cubicciotti, F. J. Keneshea, North American Aviation, Downey, Calif.
4. **Fuming of Zinc from Lead Blast Furnace Slags—A Thermodynamic Study**
   By R. C. Bell, G. H. Turner, and E. Peters, Consolidated Mining and Smelting Co. of Canada, Trail, B. C.
5. **Activities in the Lime-Silica-Iron Oxide System**
   By J. F. Elliott, Inland Steel Co., E. Chicago, Ind.

2:00 pm

COPPER

1. **Hydrometallurgy of Copper-Zinc Concentrate at the Kosaka Smelter**
   By H. Kurushima and S. Tsunoda, Dowa Mining Company, Japan
2. **Casting 3000-pound Vertical Cast Copper Slabs at Rariton Copper Works**
   By C. D. Pearce, International Smelting & Refining Co., Perth Amboy, N. J.

THURSDAY, FEBRUARY 18

9:00 am

UNCOMMON METALS

1. **Calcium Metal: Laboratory Preparation by Vacuum Metallurgy**
   By C. R. Couch and C. L. Mentell, Newark College of Eng., Newark, N. J.
2. **Methods for Separating Rare-Earth Elements in Quantity as Developed at Iowa State College**
   By F. H. Spedding and J. E. Powell, Iowa State College, Ames, Iowa
3. **Methods of Producing Rare-Earth Metals and Alloys as Developed at Iowa State College**
   By F. H. Spedding and A. Daane, Iowa State College, Ames, Iowa
4. **New Techniques in Extractive Metallurgy of Vanadium**
   By H. Mason, U. S. Atomic Energy Comm., Washington, D. C.
5. **The Production of Zirconium Boride from Zirconia and Boron Carbide**
   By C. T. Baroch and T. E. Evans, U. S. Bureau of Mines, Boulder City, Nev.

Directors Announce '54 Award Winners

At the meeting of the AIME Board of Directors on Nov. 18, the following awards were announced. Presentations will be made at the Annual Meeting of the Institute next February, except as otherwise noted.

Anthony F. Lucas Medal to Bruce H. Sage, Associate Professor of Chemical Engineering, California Institute of Technology, "for his distinguished achievements in research on the phase behavior and thermodynamics of petroleum hydrocarbons; for the development of ingenious techniques and equipment; for the study of these materials under petroleum reservoir conditions; for the resourceful application of mathematics in extending the range of prediction of the behavior of hydrocarbons over a wide range of pressure and temperature; and for his marked contribution to the present-day concepts of good petroleum engineering practice."

James Douglas Medal to W. J. Kroll "for outstanding contributions to nonferrous metallurgy, particularly in the art of lead refining and the production of metallic titanium."

William Lawrence Saunders Medal to Simeon S. Clarke, General Superintendent, Tri-State Mines, Eagle-Picher Co., "for his distinguished abilities as a mining engineer; for his resourcefulness and his genius in adapting modern and in creating new mechanical aids in mining practice; and for his notable contributions to the productivity and the longevity of the Tri-State district."

Charles F. Rand Memorial Medal to Wilfred Sykes, Chairman, Executive Committee, Inland Steel Co.

Erskine Ramsay Gold Medal to Luther C. Campbell, Vice-president, Coal Div., Eastern Gas & Fuel Associates. "Outstanding in his 35 years as engineer, operating official, and executive in the coal-mining industry have been his contributions to mechanization, safety, and the education and welfare of employes."

J. E. Johnson, Jr., Award to Robert O. MacFeeters, Assistant Superintendent of Blast Furnaces, Lorain Works, National Tube Div., U. S. Steel Corp. "for the work reported in his paper, *Correlation Between Coke Plant and Blast Furnace Operations* and his other contributions to the knowledge of blast furnace operation."

Robert H. Richards Award to C. Harry Benedict "for his pioneering achievement in the treatment of native copper ores and a half century of faithful service to his profession."

Percy Nicholls Award to Henry F. Hebley, Research Consultant to the Pittsburgh Consolidation Coal Co. "As a Fellow of the ASME and as Chairman of its Fuels Div. in 1943, and also as Chairman of the Coal Div. of the AIME in 1946, he has been especially active in promoting the aims of both societies in the field of solid fuels. His early interest in combustion and in the preparation and sampling of coal has resulted in many important contributions to the technical knowledge of those subjects. His recent activities in the control and prevention of both air and stream pollution are of outstanding value, both to his fellow engineers and to the public at large." (Awarded jointly by the Coal Div., AIME, and the Fuels Div., ASME, at the Fuels Conference, Oct. 29, 1953.)

Robert W. Hunt Medal and Award to J. B. Wagstaff, J. F. Elliott, and R. A. Buchanan for their paper entitled, *Physical Conditions in the Combustion and Smelting Zones of a Blast Furnace*, published in the JOURNAL OF METALS, July 1952. Messrs. Buchanan and Wagstaff are associated with the research laboratory of the U. S. Steel Corp., and Mr. Elliott is with the Inland Steel Co.

Mathewson Gold Medal to E. S. Machlin, Assistant Professor, School of Mines, Columbia University, and Morris Cohen, Professor of Physical Metallurgy, Massachusetts Institute of Technology, for a series of three papers: *Burst Phenomenon in the Martensite Transformation* (JOURNAL OF METALS, Sept. 1951); *Habit Phenomenon in the Martensitic Transformation* (Nov. 1951); and *Isothermal Mode of the Martensite Transformation* (May 1952).

Rossiter W. Raymond Award to Stanley F. Reiter, Research Associate, General Electric Co., for his paper, *Recrystallization Kinetics of Low Carbon Steel* (JOURNAL OF METALS, Sept. 1952).

Howe Memorial Lecturer, 1954, C. D. King, Chairman, Engineering Committee, U. S. Steel Corp.

Institute of Metals Division Lecturer, 1954, Bruce Chalmers, Professor of Metallurgy, Harvard University.

Jackling Lecturer, 1954, Reno H. Sales, Chief Geologist, Anaconda Copper Mining Co.

Fritz Award Dinner

Dinner to honor William E. Wrather, winner of the John Fritz Medal Award, will be held Feb. 4 at the Waldorf-Astoria.

Originally scheduled to be held in the Jansen Room of the hotel, it has been changed to the LePerroquet Suites.

Anton Gray Heads Committee For New Geology Volume

With Anton Gray consenting to act as Chairman, the three-man editorial committee to select material and authors for a new volume on mining geology has been completed. Other committee members are Alan M. Bateman and Donnel F. Hewett, with Reno Sales as consultant. The committee will welcome suggestions as to content and treatment of the proposed volume, which is to supersede, or bring up to date, the Lindgren Volume, *Ore Deposits of the Western States*, published in 1933.

The Lindgren volume has just been reprinted in a limited edition, to take care of a continuing demand. It is priced at $7, less 30 pct to AIME Members.

The new volume, it is anticipated, will be ready for publication within the next two or three years.

Denver Petroleum Section Recognized

First of the recently authorized "overlaying" Local Sections to be recognized by the AIME Board is the Denver Petroleum Section. Its area is to include the entire state of Colorado, the same territory that is included in the Colorado Section, but it will serve only Petroleum Branch Members. Any AIME Member in Colorado may be affiliated with either or both of the Sections.

1954 Officers Declared Elected

At the meeting of the AIME Board of Directors on Nov. 18, formal announcement was made of the election of the following "official" slate of officers for 1954, to take office Feb. 16: President-Elect, H. DeWitt Smith; Vice-Presidents, T. B. Counselman and Harold Decker; Directors, Ralph E. Kirk, Carleton C. Long, P. J. Shenon, George Dub, Earl R. Marble, and E. C. Babson. All the above serve as Directors for three-year terms. Directors ex officio, as Division Chairmen, for one-year terms: J. R. Van Pelt, MIED; J. H. Scaff, IMD; P. T. Stroup, EMD; John R. McMillan, PD; R. C. Stephenson, Ind. Min. Div.; M. D. Cooper, CD; J. S. Marsh, I&SD; J. D. Forrester, MGGD; S. D. Michaelson, MBD; and J. K. Richardson, MED. Leo F. Reinartz, currently President-Elect, will be President in 1954. One other Director is to be named for a one-year term.

Around the Sections

• H. W. Bradbury, president and general manager of Midwest Utility Coal Co., addressed the **St. Louis Section** recently on *Coal Mine Development and Mechanization*. The Bradbury mine is one of the most modern, from the standpoint of mechanization, using an incline and complete belt haulage from mine face to washing plant. Members felt this type of farsighted approach may be an aid in easing depressed coal mine conditions.

• Market history and future trends in the industrial potassium chemicals held the stage when J. A. Sheehan, district sales manager, International Minerals & Chemical Corp., Midland, Texas, spoke before the **Carlsbad Potash Section.** W. P. Wilson, Section Chairman, presided over the meeting.

• Three films of unusual interest followed the short business meeting recently held by the **Tri-State Section,** at Baxter Springs, Kan. They were *Mining in Joplin 40 Years Ago, Pay Dirt,* and *Civil Air Defense. Pay Dirt* was shown through the courtesy of the Gardner-Denver Co.

• **A 20 min, 16 mm film,** *5000 Years of Forging,* **is available to AIME Sections from Utica Drop Forge & Tool Corp. The film, in black and white, deals with the history and mechanical progress of forging from the days of primitive man. Utica Drop Forge can be reached by writing the company at its Utica 4, N. Y. address.**

Institute Meetings Now Self-Supporting

As a result of action of the AIME Board of Directors in 1949, all AIME meetings have become substantially self-supporting. In prior years, expenses in a year for these gatherings ran as high as $13,000, which was met out of income supplied by the dues of many Members who could not attend. Through the simple expedient of setting up an income and expense budget, registration or convention fees can be set at such a figure that will balance income and expense. The cost is placed solely on those who get the benefit. If an Annual Meeting is going to cost an estimated $13,000 for instance, and 2000 Members and 400 nonmembers are expected to attend, a registration fee of $5 for Members and $8 for nonmembers is indicated. Experience has shown about what income and expenses are likely to be. No attempt is made to have income enough greater than expected expense to accumulate a fund for unexpected contingencies. Expense for the social features of a meeting is a responsibility of the host Local Section; tickets are sold on a self-sustaining basis.

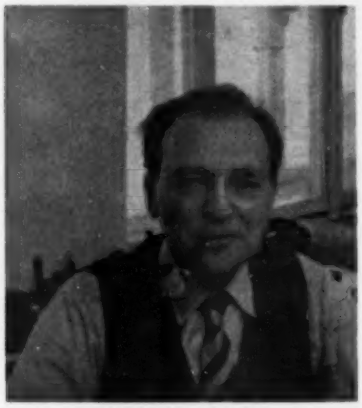
G. Holt Nominating Committee Chairman

Grover Holt, general manager, Cleveland-Cliffs Iron Co., Ishpeming, Mich., is the Chairman of the Nominating Committee for 1955 AIME Officers. Members of the Institute are invited to write to him or any other Member of the Committee, suggesting the name of a candidate for President-Elect for 1955, a Vice-President, or Director. One President-Elect is to be named, two Vice-Presidents, and six Directors.

Personals

Arnold H. Miller, consulting engineer, has returned to his offices in New York, after doing professional work in Spain, Africa and Italy.

A. S. Walter has returned to Socorro, N. Mex., after making a preliminary examination of a part of the Mouat chrome properties near Nye, Mont. Mr. Walter appeared as a witness for the Government on several cases on mining properties in the White Sands Proving Grounds. He has been doing mine appraisal for the real estate div. of the War Dept. and Justice Dept. since 1943.


TOGAN S. ONAY

Togan S. Onay has resigned as engineer at the Société Minière de Fethiye, Fetmas, Fethiye, and has been nominated a chief engineer with the Mortas Mining & Trade Co., Balikesir, Turkey.

Boris Ashurkoff has been named chief mechanical engineer, western operations, U. S. Smelting Refining & Mining Co. Mr. Ashurkoff first joined the firm when he was named mechanical engineer in 1938 for Cia. de Real del Monte y Pachuca, a subsidary. He was educated in Charlottenburg, Germany.

A. E. Roberts, Jr., mining engineer formerly with Foley Bros., Ruth, Nev., is now field editor for *Mining World* in San Francisco.

Ronald J. E. Thomas has accepted an appointment with Amalgamated Banket Areas, Tarkwa, Gold Coast Colony, British West Africa.

Ralph Flow is shift boss with Black Rock Mining Co., at Lincoln mine, Tempiute, Nev.

Benjamin H. Cody has retired from his position as chief research engineer, Morenci branch, Phelps Dodge Corp., Ariz., and has moved to Phoenix where he is doing consulting metallurgical work.

Tom Lyon, until recently director of the Domestic Expansion Div. of the Defense Materials Procurement Agency, has joined Southwestern Engineering Co., Los Angeles, as a consulting engineer. Mr. Lyon was for more than 20 years affiliated with International Smelting & Refining Co., an Anaconda Copper Mining Co. subsidiary. He was general manager from 1944 until his retirement in 1950.

Edward Martinez has left the mineral preparation div., Pennsylvania State University, to accept a position as mineral dressing investigator in the research dept., American Smelting & Refining Co., South Plainfield, N. J.

Lawrence D. Schmidt, formerly with the U. S. Bureau of Mines, is Director of Research, Semet-Solvay Div., Allied Chemical & Dye Corp., New York.

Lee R. Stoiser is with Kaiser Bauxite Co., Browns Town, Jamaica, B.W.I., where he has complete charge of exploration drilling and sampling for bauxite on the island.

Thaddeus S. Ullmann, assistant export manager of the Eimco Corp., Salt Lake City, Utah, has been promoted to export manager. Ted will continue to make his headquarters in the Eimco Bldg., 51-52 South St., New York.

William P. Horne, chemist and assayer of the Kenya Government Mines & Geological Dept., is proceeding to Australia via South Africa and England. Mr. Horne has been awarded a United Nations Fellowship in economic development.

William D. Lord, Jr., has resigned as manager of mines after six years with the International Mining Co., in Bolivia. Mr. Lord is returning to the U. S. with his family for a short vacation before seeking a new position.

John D. Ridge, associate professor and chief of the Div. of Mineral Economics, Pennsylvania State College, has been named professor of mineral economics and assistant dean, School of Mineral Industries, in charge of resident instruction. He will also continue as chief of the Div. of Mineral Economics.

Jules La Prairie, mining engineer, is with St. Joseph Lead Co., Balmat, N. Y. He was with Kennecott Copper Corp., Ruth, Nev.

Frans L. Meyjes has been made vice president in charge of production and director of the Applications Engineering Div., Anton Smit & Co. Inc., New York. **Mrs. Petronella Smit,** president, has also announced the appointment of **Daniel S. de Rimini** as general sales manager and the promotion of **Oscar A. Tellier** as treasurer.


A. T. BECKWITH

A. T. Beckwith is senior engineer, George Koch Sons Inc. at the Portsmouth Area AEC Project. In 1951, while he was plant superintendent, Lehigh Materials Co., Lansford, Pa., he was recalled by the Navy. Mr. Beckwith served for two years as assistant head, Program Development Section for Foreign Military Assistance in the office of the Chief of Naval Operations at the Pentagon.

Lloyd Allen Thomas, geologist, is with Magma Copper Co., Superior, Ariz.

Hugo E. Johnson, for the past five years assistant manager of the project development group, Battelle Memorial Institute, Columbus, Ohio, is now vice president of the Lake Superior Iron Ore Assn. The association furnishes specialized statistics on mining operations in the Lake Superior region.

Carl J. Calvin has retired as vice president of the Arthur Iron Mining Co., fiscal agent for the Great Northern Iron Ore Properties, St. Paul. Mr. Calvin, who has completed 35 years of service, will remain with the company as a consultant. Succeeding him as vice president is **Clifford McIntosh** who also continues as chief engineer. **William A. Robins** continues as assistant chief engineer, mining inspection dept. **William W. Watson** has been appointed as an assistant chief engineer, but also continues as head of the research dept.

Ernest K. Lehmann, who was a geologist with Bear Creek Mining Co., Canton, Conn., is with G-2 Section, Maneuver Director Hq., Exercise Flash Burn, Fort Bragg, N. C.

Albert Reilingh is with Barvue Mines Ltd., Barraute, P. Q., Canada. He was with Lamaque Mining Co. in Bourlamaque.

D. M. Duncan is with the 76th Tank Battalion, Fort Campbell, Kentucky. He was with Castle Dome Copper Co. Inc., Miami, Ariz.

Spencer Bowman, formerly assistant to the mining development director, Bituminous Coal Research Inc., has been put in charge of mining research development of the Cleveland Rock Drill Div., Le Roi Co., Cleveland. Mr. Bowman is directing the development of a new continuous mining machine which utilizes the principle of the experimental model developed by Bituminous Coal Research Inc. He is redesigning it for production application.

W. T. Swensen, formerly located in Potrerillos, Chile, has been transferred by Anaconda Copper Mining Co. to the exploration dept. and is now living in Toronto.

W. S. Dickie has been appointed director of the Process Equipment Div., Vulcan Iron Works, Wilkes-Barre, Pa. Mr. Dickie has been with the company since 1917.

Edward Steidle, Dean Emeritus, School of Mineral Industries, Pennsylvania State University, is chairman of the Federal Coal Mine Safety Board of Review. He was appointed to the position by **President Eisenhower** for a term to expire on July 15, 1955.

Eugene D. Neihaus, mining engineer, is with Sahara Coal Co., Harrisburg, Ill.

EDWARD I. WILLIAMS

Edward I. Williams, president Riverton Lime & Stone Co., Riverton, Va., was elected president of the Virginia Manufacturers Assn. at its 31st Annual Meeting held at the Homestead, Hot Springs, Va. Mr. Williams has been with Riverton Lime & Stone Co. since 1932 and has been president since 1941.

J. P. Gill, vice president of Vasco Canada, and executive vice president of Vanadium-Alloys Steel Co., Latrobe, Pa., was elected president of Vanadium-Alloys Steel, Canada, Ltd. to succeed **J. P. Elkann** who resigned.

B. Franklin Witmer has been appointed manager of cement equipment sales, Vulcan Iron Works, Wilkes-Barre, Pa. Mr. Witmer was formerly chief engineer of Valley Forge Cement Co. and Allentown Cement Co.

Arnold Souder, Jr., is a product engineer with Sheffield Steel Corp., Kansas City, Mo. He was chemical research laboratory assistant, Kennecott Copper Corp., Chino Mines Div., Hurley, N. Mex.

Wilfred Sykes, member of the Illinois Institute of Technology board of trustees, was honored by fellow trustees at a testimonial and farewell dinner in Chicago, Dec. 14. Mr. Sykes, former president of Inland Steel Co. and now chairman of the finance committee, is moving to California soon and will be unable to take a part in IIT, one of his major interests.

Tommy Martin, Megrine, Tunisia, 73 years old this year, is retiring from many of his engineering activities. Mr. Martin will be happy, however, to meet any AIME member who may come to Tunisia. As honorary president of the Federation des Associations d'Ingénieurs, he has contacts with all engineers in Tunisia.

Otto C. Radley, who found tungsten in Van Duzer Creek, Nev., in 1951 and traced it to a mountain now known as Scheelite Mountain expects to put in a 2000-yd capacity dredge this spring. With the help of **Henry B. Jarvis** and **Burton Jarvis**, Mr. Radley spent part of last summer and fall working the property.

J. G. Lancaster is shift boss with Amalgamated Banket Areas Ltd., Tarkwa, Gold Coast Colony, Africa.

Charles W. Punton has been appointed director of engineering of Mine Safety Appliances Co., Pittsburgh, Pa. Mr. Punton, who received his M.S. and I.E. degrees from the University of Pittsburgh, has been with the company since 1929.

Richard T. Lassiter is manager of the New York office of Western-Knapp Engineering Div. of Western Machinery Co. Mr. Lassiter was chief engineer for WKE on the White Pine Copper Co. project near Berglund, Mich.

James O. Nichols has been promoted by General Chemical Div., Allied Chemical & Dye Corp. to superintendent, Gossan mines, Galax, Va.

John W. Hamilton, secretary, Homestake Mining Co., San Francisco, has been elected to membership in the Controllers Institute of America. The Institute is a nonprofit organization of controllers and finance officers from all lines of business.

George G. Zipf is superintendent of the steel plant of the Tubular Products Div., Babcock & Wilcox Co., Beaver Falls, Pa. Mr. Zipf, who has been with B&W since 1942, was assistant superintendent of the steel plant in charge of melting and blooming.

L. Harris is assistant technical reduction officer, Taquah & Abosso Mines Ltd., Abosso, Gold Coast Colony, West Africa.

Reginald R. Whitlock, formerly with Combined Metals & Reduction, Pioche, Nev., is now with the Explosives Dept., Hercules Powder Co., Wilmington, Dela.

Jesse M. Robinson, vice president and insurance manager, Panaminas Inc., New York, has been elected for a three-year term to the board of the New York Chapter of the National Insurance Buyers Assn. Mr. Robinson is a chartered Property Casualty Underwriter and an associate of the Insurance Institute of America.

Arthur Kendall is with a Coal-Power-Tungsten Technical Team in the Orient. His address is APO 71, c/o Postmaster, San Francisco.

Peter R. Frorer of Wayne, Pa., is an ensign, U. S. Coast Guard.

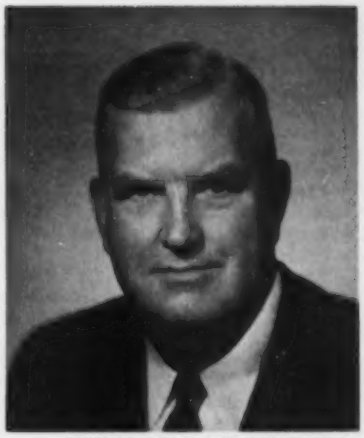
Ellis B. Gardner and **Robert A. Nilsen** have been elected vice presidents of Hewitt-Robins Inc., Stamford, Conn.

William Gladstone Jewitt, assistant general manager and manager of mines, Consolidated Mining & Smelting Co. of Canada Ltd., received the honorary degree of Doctor of Laws at a convocation held in Edmonton recently to mark the opening of the University of Alberta's new engineering building. Mr. Jewitt graduated from the university in 1923 with a B.S. in mining engineering. Four years later he joined Cominco as an exploration engineer.

Newton C. Boyd, formerly with Cia. Sud-Americana de Explosivos, Rio Loa, Chile, is now with Cia. Mexicana de Explosivos S. A., Dinamita, Durango, Mexico.

W. L. Roller, formerly with H. J. Daniels & Co., Hazelton, Pa., is a consulting metallurgical engineer, 206 W. Market St., Pottsville, Pa.

Alex Stewart has been named vice president, director, and general manager of National Lead Co. of Ohio, contract-operator of the AEC plant in Fernald, Ohio. Mr. Stewart continues as director of research for National Lead Co.



HJALMAR W. JOHNSON

Hjalmar W. Johnson, vice president of the Inland Steel Co., Chicago, spoke on *Steel* at the fourth annual Young Engineers' Forum on Nov. 24. This was the third meeting of the series that are being sponsored by the Western Society of Engineers, 84 E. Randolph St., Chicago. Mr. Johnson, the author of numerous technical papers on the steel industry, is an AIME Director and a member of the American Iron & Steel Institute. He is also a director on the Indiana State Chamber board and on the board of Western Society of Engineers.

Obituaries

L. E. Young

L. E. Young, former President of the AIME, died at his Pittsburgh home Dec. 27, 1953 at the age of 75. In addition to serving as Institute President during 1949, Mr. Young served as a Director from 1937 to 1941, and from 1950 to 1951. He was a Vice President from 1942 to 1945. After graduation from Pennsylvania State College in 1900, Dr. Young became an instructor at Iowa State College and later a professor of mining at Colorado School of Mines. After six years as director of Missouri School of Mines and Metallurgy, he left for advanced studies at the University of Illinois.

From 1918 to 1926 Dr. Young was manager of the steam heating dept. of the Union Electric Co. He was elected vice president in charge of mining of the Pittsburgh Coal Co. in 1927, a position he held until 1939. He then began a career as a consulting mining engineer with offices in Pittsburgh.

Appreciation of
David Porter Hale, Jr.
by C. G. Willard

David Porter Hale, Jr., (Member 1934) passed away on an eastern trip Nov. 3, 1953 in Philadelphia. Mr. Hale was born at Anniston, Ala., Feb. 6, 1913. He graduated from the Missouri School of Mines at Rolla, in metallurgy, in 1934. After graduation he worked for various western mining companies in Colorado and Nevada, and in December 1940 left his position as mine manager for the Cartersville Barium Corp. in Cartersville, Ga., to enter the army in the Combat Engineers Div. He saw active service with the Combat Engineers in North Africa, Italy, France, and Germany; and after V-E Day was sent to the Far East where he completed his army service as a captain in the Combat Engineers shortly after the end of the Japanese War.

Mr. Hale entered the employment of The Mine & Smelter Supply Co. Jan. 21, 1946 as a metallurgical engineer in the Marcy mill div. He was a very faithful and highly regarded employee. His death is a great loss to the company as Dave was a very brilliant and active metallurgical engineer.

Mr. Hale was married, but had no children. He was the author of a number of technical articles as regards ore milling and was very active in the AIME.

Carl Edward Julihn (Member 1905) died Aug. 8, 1953 in Washington, D. C. Mr. Julihn had been with the U. S. Bureau of Mines for 30 years when he retired in 1947 as chief engineer. An authority on strategic minerals, he was the author of numerous articles on metals and the director of several Bureau of Mines motion pictures. Mr. Julihn was born in Washington, D. C., and received his E. M. from Columbia University in 1904, his A.M. from the University of Minnesota, 1919. He did graduate work in geology, metallurgy, and mineral economics at California, Minnesota, and George Washington Universities. His early mining experience was gained in western U. S., Canada, and Mexico, much of the time as assistant to Benjamin B. Lawrence. Mr. Julihn was at various times a geologist with the Cerro Gordo Mines Co. in California, a consulting engineer for Consolidated Virginia, Virginia, Nev., and an examining engineer for British Columbia Copper Co. He joined the U. S. Bureau of Mines at the beginning of World War I and supervised the supply of war minerals. From 1918 to 1921 he was chief engineer on the War Minerals Relief Commission. Mr. Julihn served a term as member of the National Research Council.

Appreciation of
Harold Abbot Titcomb
by Henry Krumb

Harold Abbot Titcomb, internationally known consulting mining engineer, died at his home in Farmington, Maine, on Nov. 26, 1953. He was born on April 26, 1874 in Brooklyn, N. Y., and graduated with an A.B. from Shurtleff College, Ill., in 1894, and received the degree of Engineer of Mines from the Columbia School of Mines in 1898.

Mr. Titcomb's professional career began with work in the lead-zinc mines of Missouri, then as assistant manager of the Carisa gold mine, Wyoming. Then followed a number of years spent in examination and development work in the U. S., Mexico, Nicaragua, South America, and Russia, mostly under the general direction of John Hays Hammond. When the highgrade and very productive Camp Bird mine at Ouray, Colo., was taken over from Thomas F. Walsh by an English syndicate, Mr. Titcomb acted for a time as general manager for the new owners.

Later with offices in London as consulting engineer, he was associated with a Columbia classmate, Richard M. Geppert, from 1910 to 1919. The firm was very active and made examinations in many parts of the world including Siberia, Mongolia, Afghanistan, Africa, and Australia. Mr. Titcomb was consulting engineer for Esperanza Ltd. at El Oro, Mexico, for many years.

Still later he established connections with Selection Trust Ltd., London, and with another Columbia classmate, A. Chester Beatty. He continued to examine properties in various parts of the world. In 1927 he reopened a lead-zinc-silver property in Serbia, which had not been worked since the 15th century. It was incorporated as Trepca Mines Ltd., and he was its consulting engineer for 15 years, when it was expropriated by the Yugoslavian Government. Soon after the mine was reopened, King Alexander of Yugoslavia conferred on Mr. Titcomb the Order of St. Sava (Grand Officer).

H. A. Titcomb, known to intimates as Hat, married on July 8, 1908, Ethel, daughter of Mr. and Mrs. James Brignall of Wallington, Surrey, England. After the first World War he moved his family to and established residence at Farmington, Maine, to which place his great-grandfather, Stephen Titcomb, had come in 1776. The family made frequent trips to England, sometimes staying several years.

He is survived by his widow, Ethel, a daughter, Peggy, of Farmington and a son, Andrew, of Perkinsville, Vt., also by five grandchildren. Another son, Capt. John Abbot Titcomb, U. S. Marine Corps, was killed in action in Luzon, Philippines, in World War II. Those of us who knew Jack had predicted a brilliant future for him as an engineer and the sudden death of this outstanding boy was a shock from which Hat never recovered.

During the Spanish American War, Mr. Titcomb, himself, was a sergeant in the 201st N. Y. Volunteer Infantry and in World War I he

Memorial Resolution in honor of T. A. RICKARD

By the Board of Directors of the American Institute of Mining and Metallurgical Engineers

The Board of Directors of the American Institute of Mining and Metallurgical Engineers notes, with profound sorrow, the death at Victoria, B.C., on August 15, 1953, at the age of 89 years, of

THOMAS ARTHUR RICKARD

distinguished mining engineer, geologist, author, journalist, editor, philosopher, and lecturer, who joined our Institute in 1888, became a Legion of Honor member in 1938 and an Honorary Member in 1934, and who, many years ago, served our organization as Manager, Director, and Councilor.

He was born in Pertusola, Italy, August 29, 1864, next lived in Switzerland, then Russia, graduated from the Royal School of Mines, came to the United States, where he mined gold in Colorado and California, later examined mines in Western Australia, then mined in France, served as State Geologist of Colorado, examined and valued many mines for the Venture Corporation, and became editor of *Engineering & Mining Journal*, owner and editor of the *Mining & Scientific Press* in San Francisco, and later of *The Mining Magazine* in London.

He wrote many books on technical subjects, and was a great champion of clarity and accuracy in technical writing. In this respect, as in many others, he was an inspiration and example to students and young engineers. He became recognized as the leading technical editor, an outstanding technical writer, intolerant of mediocrity, a tireless enemy of chicanery and fraud, and a great exponent of straight thinking, accurate writing, ethical professional conduct, and clean living.

In many respects, he was a most unusual man; he was friendly, hospitable, companionable, interesting, forthright, stimulating, discriminating and scholarly; many members of our Institute were among those influenced, inspired, and aided by him. Therefore, be it

RESOLVED: That the Board of Directors pays tribute to the fine personal attributes, technical integrity, and inspiring professional career of T. A. Rickard, and be it further

RESOLVED: That this resolution be spread on the minutes of this meeting; and that a copy be sent to his family, together with expressions of the deep sympathy of the Board.

volunteered and served as a warrant officer in the Independent Force of the British Royal Air Force.

Hat's principal hobbies were hunting, fishing, hiking, and archery. In the latter sport he was a real enthusiast. He was a member of the National Archery Assn., Eastern Archery Assn., Maine State Archery Assn. In 1939 he was elected an honorary member of the United Bowmen of Philadelphia, which was founded in 1828 and is the oldest Archery Club in the U. S. In 1943 he was elected president of the Royal Toxophilite Society, London, which was formed in 1785, being the first and to date, the only American to receive that honor.

Mr. Titcomb was a life member of the AIME, Mining and Metallurgical Society, a Fellow of the Royal Geographical Society, London, Institute of Mining and Metallurgy, London. He was also a member of the Society of Mayflower Descendants, English Speaking Union, and the Columbia University Club, N. Y.

Hat and I have been intimate friends since college days. His sterling character, and the unique quality of his Puritanical integrity and ethics shone in his daily life, and will live, in his record. His standing as an engineer requires no elaboration from me, for it is recorded in the achievements which I have partially listed. In his passing and that of his son, Jack, the profession has lost one of its finest strains of high character, exceptional ability, and kindly attitude toward others.

Charles A. Vignos, Sr., president of American Mine Door Co., Canton, Ohio, died Dec. 1, 1953 of a heart attack. Born in Marengo, Iowa, in 1867, Mr. Vignos became well known in the mining industry because of his concern for mine safety. Under his management the company, makers of automatic mine doors, developed such accident-eliminating equipment as the electric switch throw, and many types of rock dusters for the prevention of mine fires. With a view to economy in mine operation, Mr. Virgnos also produced a track cleaner and a car transfer.

Herbert Charles Woolmer (Member 1898) died Oct. 11, 1953. Mr. Woolmer was a retired English civil and mining engineer and chairman of the board of Winchester Trust & Agency Ltd. He was born in 1871 in Deal, Kent, and studied engineering at King's College, London, where he gained a special certificate in mechanical engineering, practical metallurgy, analytical chemistry and metallurgy. His first mining experience was gained in Cornwall and coal mines in South Wales. He later managed mines in Australia, New Zealand, and Aruba, Dutch West Indies. From 1906 until 1917, Mr. Woolmer was general manager of the Spassky Copper Mines Ltd. in Russia which were closed down by the Revolution. A Legion of Honor Member of AIME, he was also a member of Institute of Civil Engineers in London.

Necrology

Date Elected	Name	Date of Death
1947	William R. Allen	Oct. 31, 1953
1932	Christian Anderson	Dec. 1, 1953
1948	Littleton Barkley	Unknown
1948	H. R. Bennett	Unknown
1952	Serge Bogroff	Sept. 24, 1953
1941	Alexander Bonnyman	May 14, 1953
1935	H. Cayford Burrell	Nov. 9, 1953
1951	J. B. Donnelly	May 7, 1953
1945	Louis J. Ensch	Sept. 9, 1953
1944	Harry S. Gay	March 1953
1920	William B. Greenlee	Unknown
1934	David Porter Hale, Jr.	Nov. 3, 1953
1937	Leroy G. Hetrick	Oct. 23, 1953
1935	F. D. Howell	Sept. 10, 1953
1914	William J. Jenkins	Jan. 12, 1953
1903	Frank G. Jewett	May 1953
1950	James K. Kent	1951
1943	Sherwin P. Lowe	Oct. 18, 1953
1948	Eero Makinen	Oct. 27, 1953
1935	Emmett McFarland	Oct. 23, 1953
1946	John L. McNulty	Aug. 22, 1953
1914	Donald Miller	July 27, 1953
1896	Carl Scholz	Nov. 15, 1953
1902	Hoval Arnold Smith	Oct. 29, 1953
1899	Harold A. Titcomb	July 18, 1953
1945	Owen F. Thornton	Nov. 20, 1953
1948	Russell F. Wilford	Aug. 6, 1953
1946	J. J. Zorichak	Aug. 6, 1953

Proposed for Membership

MINING BRANCH, AIME

Total AIME membership on November 30, 1953 was 19,562; in addition 2067 Student Associates were enrolled.

ADMISSIONS COMMITTEE

O. B. J. Fraser, Chairman; Philip D. Wilson, Vice-Chairman; F. A. Ayer, A. C. Brinker, R. H. Dickson, Max Censamer, Ivan A. Given, Fred W. Hanson, T. D. Jones, G. W. Lutjen, E. A. Prentis, Sidney Rolle, J. T. Sherman, F. T. Sisco, R. L. Ziegfeld.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

In the following list C/S means change of status; R, reinstatement; M, Member; J, Junior Member; A, Associate Member; S, Student Associate.

Arizona
Bisbee—Jett, John H. (R. C/S-S-M)
Morenci—Riley, Chleo C. (M)

Arkansas
Bauxite—Fillingham, Jack H. (J)
Bauxite—McFarlin, Jack C. (R. C/S—S-J)
Bauxite—McNish, Billy G. (J)
Benton—Stouffer, Harold W. (R. C/S—S-J)

California
Bishop—McKinley, Harold L. (R. M)
El Centro—Hess, John D. (A)
San Francisco—Felsch, Hans J. (M)
Colorado
Denver—McMichael, Harry J. (R. C/S—J-M)
Denver—Svendsen, Paul V. H. (C/S—J-M)
Golden—Coolbaugh, David F. (C/S—J-M)
Grand Junction—Schumacher, John I. (R. C/S—S-M)
Salida—Whitney, James E. (M)
Florida
Tampa—Canarlis, Svend A. (M)
Idaho
Boise—Stoddard, Bruce W. (R. C/S—S-M)
Coeur d'Alene—Scanlon, Robert H. (R. C/S—S-J)
Kellogg—Birch, Frank E. (R. C/S—S-J)
Kellogg—Gammell, Robert M. (R. M)
Illinois
Chicago—Kremm, Georges F. (M)
Chicago—Pruner, Henry E. (A)
Evanston—Silverblatt, Charles E. (J)
Springfield—Spanski, Robert F. (M)
Minnesota
Hashwauk—LeClair, William M. (M)
Hibbing—Peterson, Edward C. (C/S—J-M)
Hopkins—Keller, Leon D. (C/S—J-M)
Minneapolis—Bailly, Paul A. (J)
Minneapolis—Kaufmann, Vincent A. (M)
Minneapolis—Parker, Arthur P. (A)
Minneapolis—Ruotsala, Albert P. (J)
New Jersey
Trenton—Rider, William L. (C/S—J-M)
Westfield—Horner, George R. (M)
New Mexico
Albuquerque—Chapman, Edward P., Jr. (R. C/S—A-M)
North Carolina
Henderson—Bailey, Benton B. (R. C/S—S-M)
North Dakota
Minot—Morrissey, Patrick L. (M)
Ohio
Cleveland—Willmott, Curtis L. (A)
Hamilton—Matuszeski, Richard A. (C/S—J-M)
Oregon
Corvallis—Aho, Aaro E. (J)
Portland—Farnham, Willard (R. C/S—S-A)
Portland—West, John M. (R. C/S—S-J)
Pennsylvania
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Center Valley—Schumacker, Richard L. (C/S—J-M)
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Summit Hill—Llewellyn, Samuel W. (R. C/S S-J)
South Dakota
Rapid City—Lingard, Amos L. (A)
Tennessee
Knoxville—Sonsom, Richard E. (M)
Nashville—Pickard, Hardy O., Jr. (R. C/S—J-M)
Texas
Austin—Flawn, Peter T. (C/S—J-M)
Utah
Salt Lake City—Jerome, Stanley E. (R. M)
Vermont
So. Strafford—Benson, Clarence B. (M)
Virginia
Alexandria—Netschert, Bruce C. (C/S—J-M)
Falls Church—Forbes, Jachin M. (M)
Washington
Spokane—Lutz, Norman R. (J)
Tacoma—Bond, Frederick A. (M)
Tacoma—Jackson, Richard O. (R. C/S—S-M)
West Virginia
Huntington—Howard, Charles N. (M)
Wisconsin
Platteville—Willard, Gates (J)
Wyoming
Cheyenne—French, John (M)
Laramie—Shibler, Bertram K. (R. C/S—J-M)

Africa
So. Africa, Kimberley—Taylor, Howard H. (M)

Asia
Philippines, Baguio—Macaranas, Sofronio C. (J)
Siam (Thailand), Bhuket—Kanjana-Vanit, Rachan (M)

Canada
Salmo, B.C.—Walkey, Graham W. (M)
Rockliffe, Ottawa, Ont.—Evans, D. J. I. (J)
Montreal, P.Q.—Timmins, Leo H. (M)
Newfoundland, St. Lawrence—Seibert, Kenneth T. (R. C/S—S-J)

Europe
England, Northumberland, Corbridge—Lavers, Henry A. (R. C/S—A-M)
France, Paris—Zemp, Jacques C. (J)
Sweden, Sandviken—Haglund, Wilhelm D. (M)
Yugoslavia, Zvecan, Kosmet, Srbja—Gluscevic, Branko A. (M)

Mexico
Coahuila—Peck, De Witt C. (R. C/S—S-M)
Monterrey—Sanchez-Mejorada, Petro (R. C/S—J-M)
Parral, Chih.—Taylor, Roswell B. (M)

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— Coming Events —

Jan. 6, 1954, AIME, Chicago Local Section, Chicago.

Jan. 8, AIME, St. Louis Local Section, York Hotel, St. Louis.

Jan. 12-14, National Constructors Assn., Annual Meeting, Hotel Commodore, New York.

Jan. 13, AIME, Connecticut Local Section, American Brass Co., Torrington, Conn.

Jan. 13, AIME, Bessemer Committee, Annual Meeting, Duquesne Club, Pittsburgh.

Jan. 20, AIME National Open Hearth Steel Committee, Western Section, Rodger Young Auditorium, Los Angeles.

Jan. 25-27, Plant Maintenance & Engineering Conference, Hotel Conrad Hilton, Chicago.

Jan. 25-28, Plant Maintenance & Engineering Show, International Amphitheatre, Chicago.

Feb. 1-3, Fifth Annual Southeastern Symposium on Industrial Instrumentation, Engineering & Industries Bldg., Gainesville, Fla. Instrument Society of America.

Feb. 2, AIME, Chicago Local Section, Chicago Bar Assn., Chicago.

Feb. 15-18, AIME, Annual Meeting, Mining and Petroleum Branches, Hotel Statler; Metals Branch, Hotel McAlpin, New York.

Mar. 2, AIME, Chicago Local Section, Chicago Bar Assn., Chicago.

Mar. 8-10, American Institute of Chemical Engineers, Statler Hotel, Washington, D. C.

Mar. 10, AIME, Connecticut Local Section, American Brass Co., Torrington, Conn.

Mar. 15-19, National Assn. of Corrosion Engineers, Municipal Auditorium, Kansas City.

Mar. 17, AIME, National Open Hearth Steel Committee, Western Section, Rodger Young Auditorium, Los Angeles.

Apr. 5-7, AIME, Blast Furnace, Coke Oven, Raw Materials, and National Open Hearth Conference, Palmer House, Chicago.

Apr. 7, AIME, Chicago Local Section, Chicago Bar Assn., Chicago.

Apr. 21-23, Southern Industrial Wastes Conference, Hotel Shamrock, Houston.

Apr. 26-28, Canadian Institute of Mining and Metallurgy, Annual Meeting, Mount Royal Hotel, Montreal.

Apr. 26-30, American Society of Tool Engineers' Industrial Exposition, Convention Center, Philadelphia.

Apr. 27, Open Meeting of the Assn. of Consulting Chemists and Chemical Engineers Inc., Hotel Belmont Plaza, New York.

Apr. 30-May 1, Pacific Northwest Metals and Minerals Conference of 1954, joint meeting of Metals Branch and Industrial Minerals Div., Portland, Ore.

May 2-6, Electrochemical Society, La Salle Hotel, Chicago.

May 3-5, Coal Convention of the American Mining Congress, Cincinnati.

May 3-8, International Conference on Complete Gasification of Coal, Inichar, Liége, Belgium.

May 8-14, American Foundrymen's Society, Cleveland Auditorium, Cleveland.

Sept. 23-24, AIME Minerals Beneficiation Div., Fall Meeting, San Francisco.

Oct. 5-9, AIME Industrial Minerals Div., Fall Meeting, Whiteface Inn, Lake Placid, N. Y.

Oct. 28-29, AIME, ASME Fuels Conference, William Penn Hotel, Pittsburgh.

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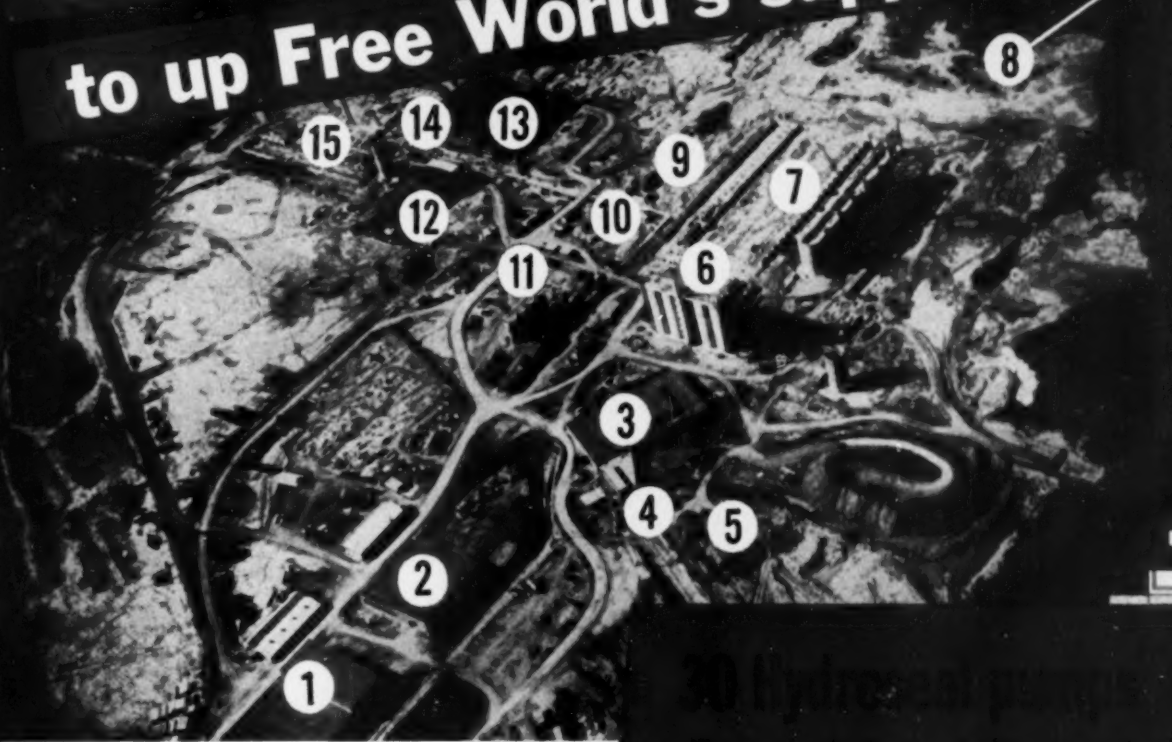

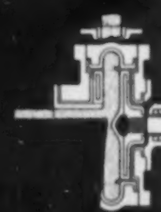

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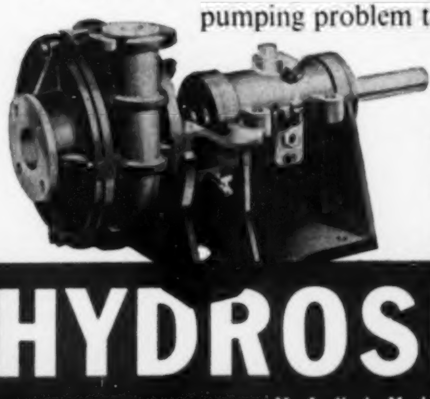

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